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RECLAMATION OF THE DOMTAR/CANADA BRICK QUARRY USING COAL FLY ASH: SUMMARY REPORT

Report No 90-326-K

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ABSTRACT

In the late 1970s, Ontario Hydro approached Domtar to use a 10 hectare portion of an operating shale quarry in Mississauga for the disposal of fly ash from Lakeview TGS and R.L. Hearn TGS. Ontario Hydro required a disposal site in order to run these generating stations and Domtar was obligated to fill the mined-out portion of their quarry. Filling of the quarry began in December, 1981, after environmental approval was granted, and the last load of fly ash was placed in December, 1986. The close out phase of the project is still ongoing. This report outlines the environmental approval process, pre-landfilling investigations and pit preparation, landfill operation and monitoring, and close out stages of the project.

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EXECUTIVE SUMMARY

Coal ash is produced by the combustion of powdered coal to generate electricity. It is composed principally of silica, aluminum and iron. These elements are the first to harden from the molten inorganics liberated from the coal during combustion and are the main constituents of fly ash. Other elements and metals, that have lower melting points, harden more slowly and are concentrated on the surface of the ash particles. Mixing of coal ash with water can release these elements from the surface of the ash particles to produce a leachate. Due to this leachate production, coal ash is considered a waste material by the Ontario Ministry of the Environment (MOE). It is, however, also recognized by the MOE as being suitable for structural fill if certain environmental control criteria are met.

Approval for the use of coal ash as a fill is normally determined by the MOE on a case by case basis. Land at several sites in the Mississauga and Etobicoke area was reclaimed in the 1960s and 1970s using coal ash from Lakeview TGS and R.L. Hearn TGS. No observable negative environmental impact resulted from these landfilling operations. Increasing public awareness of environmental issues and the "Not-In-My-Back-Yard" (NIMBY) syndrome made the process of gaining approval long and costly. This prompted the search for larger ash disposal sites so that the costs involved in the approval process could be spread over larger volumes of ash, thus keeping the "per unit" cost low.

In the late 1970s, the rate of coal fly ash production by Ontario Hydro's coal-fired thermal-electric generating stations was approximately 800,000 metric tonnes per year. A small percentage of this ash was utilized, but the majority was stored at the generating station or disposed of in landfill or reclamation sites when storage was not available at the station. Two stations in the Toronto area, Lakeview TGS and R.L. Hearn TGS, produced approximately 200,000 to 300,000 tonnes of ash per year, yet they had limited short term storage and no long term storage facilities. Ash from these stations had to be transported to disposal sites or to land reclamation areas.

The Domtar (renamed Canada Brick in 1985) shale quarry, located on the north-east corner of Dundas Street and Mavis Road in Mississauga, was recognized as being a potential disposal site which could accommodate 2 million tonnes of fly ash. The quarry was still

producing shale to manufacture clay bricks, however, a 10 hectare area within the quarry was no longer in production. Provincial regulations required that the quarry be rehabilitated, and the City of Mississauga wanted the quarry to be reclaimed so that it could be used for future residential or light industrial development. The City's plans required that Domtar infill the quarry with a structural fill material. Ontario Hydro wished to dispose of a material that met structural fill standards. Therefore, Domtar and Ontario Hydro joined together to gain approval for the landfilling project.

In order to gain approval for the project, the site was investigated by Domtar, Ontario Hydro and hydrogeological consultants, Morrison Beatty Limited. The fact that the quarry was in close proximity to residential properties to the south and east was recognized as being a potential problem. It was understood that the project would only be approved if it was judged to cause minimal impact on both the environment and the lives of residents in this area. Investigations for the project included an examination of the impact of the project on the local residents and their environment in terms of traffic volumes, noise levels, road dirt, airborne dust, groundwater contamination, and surface water contamination. All of these issues were studied by Domtar, Ontario Hydro and Morrison Beatty Limited and summarized in a report prepared by Domtar entitled "Proposed Reclamation Project for the Domtar Quarry, Mississauga, Environmental Report" (the "Blue Book"), dated June 1980. This report was submitted by Domtar to the MOE on June 25, 1980, along with an application for approval to reclaim the quarry using coal fly ash produced by Ontario Hydro's coal-fired generating stations.

Environmental Assessment Board (EAB) hearings began in January, 1981, with evidence being presented by all parties concerned with the project. Findings from these hearings indicated that the landfilling project would have little effect on the lives of residents living near the quarry and would improve the local environment by reclaiming unusable land. Approval for the project was granted after the EAB hearings and with the assurance that environmental protection and monitoring criteria would be met. This approval came in the form of a Provisional Certificate of Approval # A220113, issued by the MOE on August 18, 1981, for the use of coal ash for landfilling in the Canada Brick Quarry.

Filling of the quarry was preceded by construction of an access road, preparation of the quarry bottom, and the installation of drainage control for surface water and underdrainage for the ash fill. The first fly ash was deposited at the site on December 18, 1981, after the conditions in the Provisional Approval Certificate had been satisfied. The total coal ash deposited over the life of the project was about 683,927.4 tonnes or 553,130.1 cubic metres. The last load of ash was placed at the site on December 30, 1986. Substantially less than the estimated 2 million tonnes were placed at the site. This was a result of the upper ash fill level being lowered from 120 m a.s.l. to 117 m a.s.l., fluctuating ash production, the use of material other than ash for construction of the access road, and the use of berms and caps of other materials to encapsulate the ash into "cells".

Initial estimates of 220,000 to 330,000 tonnes per year were used to schedule the filling project. The actual production rate fell below these figures due to an economic recession and another generating station coming on line. Actual ash production was in the order of 150,000 to 200,000 tonnes per year. After completion of the filling project, the ash was covered with a "seal" layer. This layer consisted of at least 1 m of clay or till compacted to structural fill standards with an in situ hydraulic conductivity no greater than 10^{-7} cm/s. A 1 m thick protective cover layer was later placed on top of the seal layer to protect it from desiccation cracking and frost heave. Material is currently being stockpiled at the site to increase the thickness of the protective layer. Eventually, this material will be spread, compacted to structural fill standards, and contoured to improve surface drainage and avoid ponding. This will ultimately make the site "self-managing", as is required by the MOE. The estimated completion date for the project should be some time in 1991, the exact date being a function of the availability of suitable fill material.

The details of the Canada Brick Quarry reclamation project from its inception to the current date at which the project is near completion are summarized below. To date, this has been a very successful filling operation and is an excellent example of how fly ash can be used beneficially. This report summarizes all of the aspects involved in gaining environmental approval, project operation, problems, monitoring, public relations and other factors that were important to the approval and operation of the landfill.

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To Mr. H.H. Leng
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RECLAMATION OF THE DOMTAR/CANADA BRICK QUARRY USING COAL FLY ASH: SUMMARY REPORT

1.0 INTRODUCTION

Electricity is produced at coal-fired thermal generating stations by the combustion of coal. Powdered coal is blown into the boiler where it ignites and the heat produced is used to superheat water to form steam. This steam is then used to turn turbines which are connected to generators. Coal fly ash is composed of the inorganic components of the powdered coal that are not consumed during the combustion process. These materials are liquified by the intense heat and carried upwards where they cool to form silt-sized glassy spheres that are removed from the flue gases by electrostatic precipitators. A heavier slag-type ash, bottom ash, collects in the boiler and is later removed with high pressure water-jets. The grain size distribution of fly ash and bottom ash can be seen in Figure 1/1/.

Coal ash is composed principally of silica, aluminum and iron. These elements are the first to harden from the molten inorganics liberated from the coal during combustion and are the main constituents of fly ash. Other elements and metals, that have lower melting points, harden more slowly and are concentrated on the surface of the ash particles. Mixing of coal ash with water can release these elements from the surface of the ash particles to produce a leachate. The results of a typical leachate test are shown on Table I/1/. Due to this leachate production, coal ash is considered a waste material by the Ontario Ministry of the Environment (MOE). Nevertheless, fly ash is also recognized by the MOE as being suitable for structural fill if certain environmental control criteria are met/2/.

In the late 1970s, the rate of coal fly ash production by Ontario Hydro's coal-fired thermal-electric generating stations was approximately 800,000 metric tonnes per year/2/. A small percentage of this ash was utilized, but the majority was stored at the generating station or disposed of in landfill or reclamation sites when storage was not available at the station. Two stations in the Toronto area, Lakeview TGS and R.L. Hearn TGS, were producing approximately 200,000 to 300,000 tonnes of ash per year, yet they had limited short term

storage and no long term storage facilities. Ash from these stations had to be transported to disposal sites or to land reclamation areas.

The Domtar (renamed Canada Brick in 1985, therefore both names are used in this report) shale quarry is located on the north-east corner of Dundas Street and Mavis Road in Mississauga, as shown in Figure 2. In the late 1970s, it was recognized as being a potential disposal site which could accommodate 2 million tonnes of fly ash. The quarry was still producing shale to manufacture clay bricks, however, a 10 hectare area within the quarry was no longer in production. Provincial regulations required that the quarry be rehabilitated and the City of Mississauga wanted the quarry to be reclaimed so that it could be used for future residential or light industrial development /3/. The City's plans required that Domtar infill the quarry with a structural fill material. Hydro wished to dispose of a material that met structural fill standards. Therefore, Domtar and Hydro joined together to gain approval for the landfilling project.

The details of the Canada Brick Quarry reclamation project, from its inception to the current date at which the project is near completion, are summarized below. To date, this has been a very successful filling operation and is an excellent example of how fly ash can be used beneficially. This report summarizes many of the aspects involved in gaining environmental approval, project operation, problems encountered, monitoring programs, public relations and other factors that were important to the approval and operation of the landfill.

2.0 ENVIRONMENTAL APPROVAL

In order to gain approval to use Ontario Hydro coal fly ash as a structural fill material for the reclamation of the Domtar quarry, certain steps had to be followed. These steps included: an office and field study of the landfilling area, application submission, and Environmental Assessment Board (EAB) hearings. Due to the size and nature of this project, several organizations were concerned with the approval and participated in the environmental hearings. The groups involved with the approval process and the steps followed are discussed below.

2.1 The Players

A project of this size and type involved the participation of many parties. The principal proponents of the project were Ontario Hydro and Domtar. Those who were also concerned with the project included the City of Mississauga, the Region of Peel, and local residents' groups such as the East Huron Park Home Owners Association (EHPHOA). The MOE was the regulatory body responsible for conducting hearings to determine the concerns of those involved, and to decide if the application should be approved or rejected. Below is a brief discussion of those involved with or interested in this project.

The MOE was involved in this project as part of their regulatory function. Their responsibility was to listen to the arguments presented at the hearings and then grant or

deny approval based upon the evidence. They wanted to ensure that the residents in the area surrounding the quarry were not adversely affected by the operation, and to determine whether this project would be beneficial or detrimental to the environment in the long term. Also, if the project were approved, they required that it be operated within MOE guidelines.

Domtar was involved in this project as one of the two proponents. They had been mining shale from this quarry since the late 1950s. Domtar wished to have the mined-out portion of their quarry filled so that they could meet Provincial guidelines for pit infilling and City of Mississauga guidelines for future land use. They were approached by Ontario Hydro to use coal ash as a structural fill for this reclamation project. The use of fly ash was appealing to Domtar because a sole source fill supply presented fewer quality control problems than earth landfill from many sources. Domtar was interested in handling the project in an efficient manner that would lead to the development of potentially valuable land and enhance public relations.

Ontario Hydro was also a proponent of this project. Two of Hydro's coal-fired generating stations had limited on-site storage. In order to operate Lakeview TGS and Hearn TGS, Ontario Hydro needed a disposal area for coal ash. Disposal at rural landfill sites was expensive in terms of both transportation costs and tipping fees. The Domtar quarry could provide Ontario Hydro with a local site having a potential life of 10 to 15 years. Ontario Hydro's main goal was to dispose of their fly ash in a low cost, environmentally sound manner to meet MOE requirements. They also wished to ensure the smooth, orderly operation of the project to maintain a good corporate image and to ensure that future ash filling operations were greeted optimistically. Ontario Hydro had previous experience with successful ash landfilling operations, which was a valuable asset for seeking environmental approval.

The major opponents to the project were the citizens living near the quarry, in particular the EHPHOA. They were concerned for their health and losses in property values. A full discussion of these concerns is given in a later section of this report entitled "Public Concerns".

The Region of Peel had certain interests in the project. The Region was concerned that leachate from the site might be disposed of in the Regional sewage system, that industrial wastes other than coal ash might be disposed of at the site, and that traffic from the project might cause problems along routes from the generating stations to the quarry. Their goal was to ensure that the project was operated such that these problems did not occur.

The City of Mississauga had a lengthy list of concerns about the project. Many of the City's concerns reflected those of the populace living near the site. The City requested that all construction noise levels, monitoring techniques, environmental controls and leachate concentration levels meet MOE requirements. The City also wanted to ensure that the quarry be reclaimed in such a way that future residential or light industrial development at the site would be possible.

2.2 Information Requirements

An assessment of the impact of this project on the local environment was considered necessary before filing an application for environmental approval with the MOE. Desk and field studies were conducted by Domtar, Ontario Hydro, and their consultants. The findings from this study were summarized in the report prepared by Domtar Inc. entitled "Proposed Reclamation Project for the Domtar Quarry, Mississauga, Environmental Report"/4/. During the EAB hearings it was observed that there could be a lack of hydrogeologic data. Further investigations were done and the data was included in a report prepared by Morrison Beatty Limited, a hydrogeological consultant, entitled "Domtar Quarry, Reclamation Project Mississauga, Hydrogeologic Study (Supplemental)"/5/.

These reports included: topographic, geologic and hydrogeologic surveys, noise and traffic studies, monitoring programs for groundwater, surface water and dust, general site operation guidelines, past experience with ash landfilling, and end use plans for the quarry upon the completion of filling. These reports were essential to the application process as they showed the MOE that Domtar and Ontario Hydro had considered the possible effects of the project on the local environment and were concerned about minimizing this impact. Below is a discussion of some of the information contained in the reports.

2.2.1 Topographic Survey

A survey of the site was done to determine the topography of the quarry and surrounding area. Prior to the topographic mapping of the quarry bottom, an existing "pond" had to be pumped from the pit floor. Detailed topographic surveys were done in order to determine drainage patterns and establish watersheds.

The topographic mapping of the quarry bottom was an important aid for the design of underdrainage for leachate collection and water table control. It was also used for the positioning of berms to keep fresh water from flowing into the ash cells from other parts of the quarry floor. The topography of the area surrounding the quarry was used to establish the locations of berms and drainage trenches to be used to minimize surface water drainage into the quarry.

A topographic map of the quarry can be seen in Figure 3.

2.2.2 Geologic Survey

A study of the geology of the area indicated that the quarry was located in the Dundas shale of the Georgian Bay Formation. This shale is over 120 m thick in the Toronto area. Much of the shale in the area of the quarry is overlain with between 1 to 3 m of a sandy silt till. The upper 3 to 5 m of the shale exhibited weathering and extensive fracturing, however, these features decreased with depth/4/. The shale formation was the dominant geologic unit for the purpose of this project and studies of hydrogeology in the area focused on the shale unit. Figure 4/3/ shows some geologic cross-sections through the quarry.

2.2.3 Hydrogeologic Investigations

In order to determine the hydrogeologic conditions at the site prior to landfilling and to monitor the future effects of leachate from the ash on the groundwater quality, a series of observation wells were drilled. Initially, 15 wells were installed around the site and these were used to establish the hydrogeologic environment and water quality. Well locations and depths were chosen carefully by Morrison Beatty Limited, a hydrogeological consulting firm, in order to gain a full understanding of the hydrogeology of the shale in the quarry and surrounding area. The positioning of the initial wells was restricted by the residential areas to the south and east of the quarry, so they were confined predominately to Domtar property.

During the early stages of the EAB hearings, Dr. J. Cherry, a noted hydrogeologist, stated that he felt there were not enough wells to fully describe the hydrogeology of the site and surrounding area. Another 18 wells were installed in road allowances in the residential area south of the site. The locations of these additional wells were determined by both Dr. Cherry and Morrison Beatty Limited. When additional information was obtained from these wells, Dr. Cherry stated he was comfortable with the interpretation of the hydrogeologic environment made by Morrison Beatty Limited. Figure 5/6/ shows the locations of observation wells as of September, 1983. Very few changes in the observation well inventory occurred after the supplemental investigation and prior to the preparation of the map shown in Figure 5.

The monitoring wells at the site were constructed as shown in Figure 6/5/. All wells were installed by experienced staff from the Civil Research Department of the Ontario Hydro Research Division (OHRD). PVC piping was used to line the observation wells because of its durability and because it is inert. Metal pipes can corrode and increase the ion content of water samples, thereby influencing water quality analyses. The two main objectives of the hydrogeologic survey were to gain understanding of the groundwater flow and to determine the existing water quality.

Tests, directed by Morrison Beatty Limited, were done to determine the permeability of the shale underlying the landfill site. These included bail-down and pressure packer permeability tests. The permeability of the shale was found to decrease with depth, as shown in Figure 7/3/. This was likely due to the decrease in fracturing and weathering of the shale with depth. Piezometric data from the monitoring wells indicated that the general groundwater flow direction was downwards to the southeast. The vertical gradient ranged from 0.3 to 0.8 and the horizontal gradient averaged 0.01 in the southeast direction. It was estimated that any leachate entering the groundwater in the future would follow this same flow direction and should show up in down-gradient monitoring wells/4,5/.

Investigations of groundwater quality were conducted on a regular basis by staff from the Chemical Research Department of OHRD. In order to guarantee that it was indeed the groundwater that was being sampled, each well was bailed-down and allowed to refill before samples were taken. This ensured that water that may have seeped in from the top of the

well did not influence the test results. Both field-filtered and unfiltered water samples were taken from the monitoring wells. This was done to ensure that the sampling method had no effect on the test results as Dr. Cherry had indicated during the EAB hearings that it might. Unfiltered samples were stored overnight in the laboratory at 4°C and then filtered the following day. Samples were both filtered in the same way using a 0.45 μm glass fibre filter to remove suspended solids. Groundwater samples were analyzed for major ions, nutrients, organics, and trace elements. Both field-filtered and laboratory-filtered samples yielded similar results/4,5/.

The results of the chemical analyses indicated that the background groundwater quality was poor. This was further corroborated by the fact that there were no drinking water wells in the shale formation. A survey of 9 private wells in the area that were in the Dundas shale formation showed that the water quality and yield were both so poor as to preclude the use of these wells for virtually any purpose /4/. Water quality changes with depth were also observed. The surficial groundwater zones had a bicarbonate character and the deeper zones had a chloride character. This is typical of a recharge area, since long term flushing by recharge water leaches the soluble elements from the shale beds causing different water chemistry with depth/4/. These chemical findings reinforced earlier measurements indicating that groundwater flow was downward. Table II/5/ illustrates the quality of the groundwater in the quarry area prior to landfilling with ash.

A groundwater seepage spring in the residential area southeast of the quarry was also examined during the field investigations. The elevation of the seepage area was found to be 3 to 4 m higher than the maximum recovered water table elevation expected in the south end of the quarry upon completion of the filling project. This indicated that the spring was caused by local groundwater mounding, most likely as a result of the construction of Dundas Street. The seepage area was not a result of any activities at the Domtar quarry, nor would it be influenced by the landfilling project/5/.

In conjunction with the groundwater investigation program, a study of surface water around the quarry was also done. This study focused on the principal surface watercourse, Mary Fix Creek. The creek ran along the eastern edge of the Domtar property, flowing from north to south. Water samples and flow measurements were taken at four locations along the creek, both upstream and downstream of the quarry, to determine the flow characteristics and water quality of the creek. Sampling and testing was also done by personnel from OHRD. This study was done so that any effects of leachate from the ash on surface water quality could be determined and so that rates of water discharge from the quarry into the creek could be calculated such that they would not have a harmful effect on the flow rates or water quality of the creek/4,5/.

2.2.4 Noise and Traffic Studies

Studies were done by staff from OHRD to determine the impact of truck traffic and operating noises on the lives of residents living near the quarry.

Based upon ash production forecasts, the number of trucks travelling to the site on a daily basis was estimated. Preferred trucking routes were chosen by collaboration with the City of Mississauga Traffic Section and the Region of Peel Transportation Planning Department. Hours of operation were determined to be Monday to Friday, 7:00 am to 4:00 pm. Based upon these hours, and the routes suggested by the City and the Region, the effects of the increased traffic density on the various routes were determined. The increase in truck traffic due to the filling operation was found to be less than 10% of the existing truck traffic /4/.

Noise studies were also done by OHRD staff. Rigorous measurements of ambient noise levels in residential areas adjacent to the quarry were conducted. Measurements and predictions were made of the noise levels due to the equipment required for the landfilling operation. This study indicated that the predicted one hour equivalent sound level from the landfilling operation at the community closest to the quarry would be less than the lowest one hour equivalent sound level due to local industry and existing road traffic combined. It was estimated that the combined sound levels of ambient and landfilling noise would still meet the guidelines for community noise levels set by the MOE/4/.

2.2.5 Monitoring Programs

Monitoring programs for compaction control, water quality changes and dust emission measurement were proposed by Domtar and Ontario Hydro. It was suggested in the reports that Ontario Hydro would work with Domtar to ensure that ash spreading and compaction were being done properly. Domtar indicated that their personnel would conduct regular compaction monitoring, with assistance from Golder Associates, to ensure that density requirements for a structural fill were being achieved/4/. The groundwater and surface water monitoring programs included regular sampling and testing of water taken from the wells drilled for initial studies and from sampling points used for surface water characterization. A full discussion of the actual water monitoring program that was used is given in a later section of this report. Measurement locations for fugitive dust emission from the landfilling operation were planned for several points around the quarry. The actual locations and measurement methods are also given in a later section of this report.

The monitoring programs for compaction, water quality and dust were approved by the Director of the Environmental Approvals Branch of the MOE prior to the commencement of landfilling.

2.2.6 Site Operating Guidelines

Ontario Hydro's previous experience with ash utilization and Domtar's familiarity with quarrying operations were used to outline the quarry filling operation guidelines.

Prior to filling, the quarry had to be prepared so that the ash could be properly placed and compacted and ash leachate could be controlled. This pit preparation included the construction of an access road into the filling area so that trucks could enter the quarry in a quicker, more efficient and safer manner. The quarry floor had to be prepared by

removing or compacting loose debris and weathered shale to facilitate easier equipment operation and provide a stable base for compaction of the fly ash to structural fill standards. An underdrainage system to collect ash leachate and control water table rise in the quarry was also recommended as a contingency plan to prevent future migration of ash leachate/4/. Each of these quarry preparation steps is discussed further in later sections of this report.

The filling operation was restricted primarily to Mondays to Fridays inclusive from 7:00 am to 4:00 pm. Some provisions were made for filling after these hours or on weekends during periods of high ash production. Ash was to be hauled to the site along specific trucking routes and in covered trucks to prevent dusting. Volumes and weights of ash entering the quarry would be determined from truck weighing or estimated from vehicle haulage capacity. The ash was to be delivered to the site with a moisture content of about 15% to prevent dusting and spread by bulldozer in 25 to 30 cm lifts to allow for compaction. Moisture content, prior to compaction, was to be raised nearer to optimum by a water spray truck. Equipment for spreading, compaction and dust control was specified. Compaction testing on a regular basis by Domtar was recommended in order to ensure that the quality requirements for a structural fill were being achieved/4/.

2.2.7 Ash Landfilling Experience

Landfilling with ash for land reclamation and as a structural fill was a familiar project for Ontario Hydro. Several sites in Ontario had been successfully filled with fly ash with no observable negative environmental impact. In fact, many of the filling projects had improved the local environment by turning previously unsightly or unusable land into land that could be used beneficially. Some of these sites are described briefly below.

During 1962 to 1968 over 900,000 tonnes of coal ash from Lakeview TGS and R.L Hearn TGS was used to fill low lying land at Dixie Road and Britannia, known as the Ambler Courtney Site/4/. Ash was placed at the site by end-dumping and spread by bulldozers, without compaction/2/. The fill ranged from 10 to 14 m in thickness across the site. In late 1979 this site was investigated by William Trow and Associates as a possible site for industrial development. This investigation showed that the ash fill was able to support 1 to 2 storey buildings with only slight improvement of the ash adjacent to the foundations/2/.

From 1968 to 1972 over 450,000 tonnes of coal ash were used to reclaim an abandoned gravel pit along the North Service Road, west of Mississauga Road. The pit was being used as an uncontrolled garbage dump and landfilling it with ash ended this public nuisance. The land was not used for construction, but was instead used to develop Oakridge Park, a beautiful public park/4/.

Birchwood Park in Mississauga, along the north side of Lakeshore Road West, represents a similar site where ash was used to reclaim an abandoned gravel pit to develop parkland. From 1967 to 1974 coal ash was placed at this site in order to reclaim the land. The result was a beautiful public park and toboggan hill /4/. Thirty-three piezometers were placed at this site in 1978 in order to study the effects of the ash on the groundwater quality. This

study showed that leachate leaving the site did not contain toxic levels of heavy metals. Also the water chemistry down-gradient of the site reverted quite rapidly to approximately the same quality as the up-gradient water. Water quality was improved by dilution, dispersion and attenuation by the soil in the ground surrounding the site/5/.

The Booth Quarry site, on Horner Avenue, west of Kipling Avenue, in Etobicoke, represented a site where both pre-filling and post-filling groundwater monitoring had been done. Prior to the commencement of ash landfilling at the site, groundwater samples taken from the central sump of the quarry and from monitoring wells around the site were analyzed to establish the background water quality. Almost 700,000 tonnes of coal ash was placed in this abandoned shale quarry from 1976 to 1980 to reclaim the quarry to develop a local park. No impairment of local groundwater quality due to the placement of ash was observed during the life of the landfilling project/5/. This project was supported by the MOE and praised by Etobicoke Mayor Dennis Flynn. Mayor Flynn sent a letter to Ontario Hydro stating that he was pleased with the efficient way in which the filling operation had been completed and the minimal degree of adverse impact upon nearby communities that occurred during the project/4/.

2.2.8 Land Use Plan

Two plans outlining possible land use were presented in the Domtar report. The first plan gave no rigid guidelines for future land use. This plan was described as "providing maximum flexibility for various types of ultimate land use"/4/. The second land use plan was prepared in general accordance with the Dundas-Fairview Secondary Plan, Amendment 280, outlined by the City of Mississauga. This called for future residential or light industrial development at the site. A discussion of revisions to these plans was also given should ash production fall short of or exceed predicted amounts. The consulting engineering firm of Marshall Macklin Monaghan Limited prepared drawings of the land use plans. These plans were included in the report/4/.

2.3 EAB Hearings

As part of the approval process normally conducted by the MOE for projects of this type, a series of EAB hearings were held. During these hearings, all parties, both in favour of and opposed to the project, were allowed to present their arguments. A pattern was followed during the presentation of the information. One by one a series of witnesses were called to testify on various aspects of the project. Each was questioned by an initial examiner and then cross-examined by others. The testimony of these witnesses was noted by the chairman and members of the EAB and used to determine the outcome of the application request. Below is a listing of the expert witnesses called to testify at the hearings.

2.3.1 Expert Testimony

John Nicks of Domtar was called as a witness to give the board a description of the quarry and an outline of mining procedures used by Domtar. He also gave a brief description of

the planned operating practices for the ash filling project, which included ash spreading and compaction, compaction monitoring, dust control, dust monitoring, hours of operation, surface water control, leachate control and proposed end-use for the land/2/.

Robert Bee, a Marshall Macklin Monaghan employee hired by Domtar as a landscape specialist, was called to describe the effects of filling the quarry with ash on the topography of the area. Mr. Bee presented three scenarios of how the pit would look if different volumes of fill were placed. Diagrams showing the possible pit configuration if 1, 2, or 4 million tonnes of fly ash had been placed in the quarry were presented. Mr. Bee was able to state that these filling alternatives would provide a final topography that would be suitable for the land use specified by the City of Mississauga. Contour plans and cross sections showing the various filling levels were given in the Domtar report.

J.H.P Buckingham, an Ontario Hydro employee in charge of ash management and Ontario Hydro's leader for this project, was called to testify on the experience of Ontario Hydro with ash disposal projects. Mr. Buckingham gave a brief description of the origin of coal and coal ash and stated that coal ash is very similar in composition to some natural shales and clays. He also discussed European utilization of coal ash which had been widespread for many years. American experience, which included reference to the Adena housing development, in West Virginia, built directly on ash, was also mentioned. The fact that there had been no settlement, corrosion or other problems with houses built directly on ash was emphasized. Ontario Hydro's experience with using coal ash as a fill material for reclamation projects in the Mississauga area was also mentioned. The lack of storage facilities at Lakeview TGS and R.L. Hearn TGS was referred to and the need for land reclamation projects such as this quarry was stressed. Estimates of the quantities of ash that were expected to be available, the number of trucks required to haul the ash, and the proposed trucking route to the quarry were also presented.

Dr. T.W. Klym of the Civil Research Department of OHRD was called as a witness to present information on the hauling and placement of ash. Dr. Klym's testimony included a discussion of case histories of ash filling projects that Ontario Hydro had been involved with. This included a discussion of the 20 year old Ambler Courtney ash disposal site at which ash had simply been dumped into a pit. Investigation of this site by a soils consultant found that this ash could support industrial development with only slight improvement to the ash adjacent to the foundations. He also mentioned the Adena housing project in West Virginia where houses were built directly on coal ash. Dr. Klym then described how the Domtar quarry would have to be prepared by pumping out pooled water, the removal or compaction of loose material on the quarry floor, and the installation of an underdrainage system. He also went into great detail as to how the ash was going to be placed and compacted in order to make it a suitable structural fill and to limit dusting problems. This included ash moisture control and compaction monitoring. Dr. Klym also stated that Ontario Hydro was willing to work with Domtar staff during the landfilling operation to assist them with any problems that might occur/2/.

John Kowalewski of the Mechanical Research Department of OHRD was asked to testify on the noise generated by the filling project and its potential effects on the lives of local residents. Mr. Kowalewski described how he followed MOE procedures for noise measurement. He reported that he had carried out measurements of ambient noise levels at various points around the quarry. Mr. Kowalewski then presented measured and estimated levels of noise due to the operation of equipment at the site. The landfilling noise levels were found to be below the ambient noise levels and thus the operation was expected to have no impact on the residents in terms of noise/2/.

Mr. D.J.R. Dodd of the Chemical Research Department of the OHRD testified that the chemistry of the coal ash was similar to the chemistry of the shale into which the ash was going to be placed. Coal ash is composed primarily of silica, aluminum, and iron, as is shale. Table III lists the chemical components of coal ash and shale/4/. A similar table was presented at the EAB hearings as an exhibit to show that the material proposed for the filling project was very similar to the material previously removed. Mr. Dodd also discussed Ontario Hydro's experience with monitoring ash landfills and examining the leaching characteristics of coal ash. He mentioned that environmentally significant elements could leach from the ash but that their concentrations were generally at or below MOE objectives for surface water quality. He also described leaching tests that had been used by Ontario Hydro to estimate the concentrations of the elements leached from fly ash/2/.

Brian Beatty, a hydrogeologist, was at the EAB hearings to discuss the hydrogeologic environment at the quarry and to describe the effects of filling the quarry with ash and allowing the groundwater table to rise to its natural elevation. Mr. Beatty described how the observation well locations had been chosen and how the site had been characterized. This included a discussion of the instrumentation, field, and laboratory tests used to gain hydrogeologic information about the site and the region in general. He also discussed how the surface drainage and underdrainage could be used to control leachate migration and how monitoring of leachate migration should be carried out. Mr. Beatty commented on a section of a report by Dr. Cherry that stated that the investigation program was insufficient to fully describe the hydrogeologic conditions at the site. He stated that there might be a shortage of data, however, this would be resolved by the installation of additional observation wells once "rights-of-way" could be established in the residential area south of the quarry. Initially Mr. Beatty could not comment on the seepage area south of the quarry that was evident in some backyards. When recalled to the witness stand, after visiting the seepage area, he was able to explain that it was caused by the fill and the drainage system used in the construction of Dundas Street and would not be affected in any way by the landfilling operation/2/.

Dr. I.H. Joyce of Domtar discussed some of the measures taken by Domtar to inform local residents and interest groups about the project. Newspaper advertisements were published, handbills were distributed to local residents, and public information sessions were held. He stated that some confusion about the dates of the public meetings had likely caused more interest in the project than what would normally have been generated. Both Domtar and Ontario Hydro provided staff to field questions at these information meetings/2/.

Robert Moffat, a local resident who lived close to a seepage area south of the quarry, was called as a witness to describe the seepage area and how it affects local residents. Mr. Moffat was concerned that filling the quarry with ash and allowing the water table to return to its natural position would cause an increase in seepage from the area behind his house and that the seepage would be hazardous. He disagreed with Mr. Beatty's comment that the seepage area was caused by the construction of Dundas Street, and not by the quarry. Since he was not a technical expert, however, his testimony was tenuous.

Dr. J. Cherry, a hydrogeologist hired by the City of Mississauga and the EHPHOA to examine the Domtar report, presented his interpretation of the available hydrogeologic data. He stated that he felt that there was a shortage of data which precluded accurate determination of the hydrogeologic environment and he questioned the methods used to obtain elemental concentrations in the groundwater. Dr. Cherry agreed to cooperate with Domtar, Hydro, and Morrison Beatty Limited in locating more boreholes to get additional data. The EAB hearings were adjourned for three months while this extra work was done. The data collected from these boreholes was used to prepare a supplemental report. Upon examination of the additional data, Dr. Cherry agreed with the interpretation of the hydrogeologic environment presented in the supplemental report submitted by Morrison Beatty Limited/2/.

In response to public health concerns regarding fly ash, Dr. T.R. Hamilton, a health specialist working for Hydro, explained that fly ash is nothing more than a nuisance dust. Dr. Hamilton discussed fly ash effects on people and a Davis University report that was mentioned at the hearings. He dismissed this report by stating that only one test result out of many samples showed the ash to be hazardous. This result was likely from an ash produced in a different temperature environment from normal fly ash. Dr. Hamilton stated that he knew of no reliable reports that found airborne coal fly ash to be a hazard to human health. He stated adamantly that coal fly ash was nothing more than a nuisance dust /2/.

2.3.2 Public Concerns

Concern for this project was expressed by many residents living near the quarry who attended the EAB hearings. A brief discussion of these concerns is given below.

Primarily, the residents were worried that their health could be in danger. The report prepared by Davis University was mentioned at the EAB hearings. This report included findings that fly ash could be carcinogenic. Breathing problems, silicosis and allergies were also foreseen by the residents as being the product of this project. The citizens were concerned that they were being exposed to an unnecessary risk and would be in even greater danger than those working with the ash. Even though Dr. Hamilton of Ontario Hydro stated adamantly that fly ash was nothing more than a nuisance dust and would cause no detrimental health effects, the public was still wary of possible health hazards from fly ash/2/.

Local residents were also concerned about air pollution generated by fugitive fly ash. Aside from the health concerns mentioned above, people were concerned that blowing ash might cause poor visibility and lower the overall appearance of their possessions by covering them with a layer of dust. A cardboard fire at the quarry that sent ash into the air and covered the rooftops and cars further fuelled residents' concerns. They associated the cardboard ash with fly ash and they were worried that their homes and cars would be regularly covered with ash. Coal ash is quite different from paper ash and proposed operating procedures were such that excessive ash dust release from quarry was not foreseen/2/.

The possible negative effect of the project on their property values worried local citizens since the size and duration of the project was not accurately known. They were worried that the project might have an initial life of 10-15 years that would later be extended to 25-30 years. This worry was eased by the knowledge that only a portion of the quarry was going to be filled, and that if further work was going to be done, another application would be filed with the MOE. The size of the project worried people as they were concerned that neither Domtar nor Ontario Hydro would accept responsibility for fugitive ash. This worry was dispelled by the assurance that Hydro would be responsible for the ash being transported and Domtar would be responsible for the ash once it had been unloaded at the site/2/.

A seepage area, evident in some backyards south of the quarry, was also a concern for some residents. The people in this area associated the seepage with water from the quarry. They were worried that if the quarry was filled with ash and the water table was allowed to return to its natural level, that the seepage rate would increase and that the seepage water could be toxic. It was shown, however, that the seepage area was a result of the construction of Dundas Street, and not due to the quarrying operation. Water from the quarry would not permeate from this seepage area/5/.

The residents of this area were also particularly sensitive to industrial operations and hazardous substances in their area. Approximately one year prior to this proposal, there had been a train derailment along the CPR tracks near Mavis road causing chlorine gas to be released into the air and the residents had to evacuate their homes. Any project that was perceived as having even the slightest effect on their lives was therefore looked upon unfavourably. The residents identified fly ash as being a possible airborne hazardous material that might cause a similar health worries/2/.

2.3.3 Findings

Some of the findings presented during the hearings that supported the approval of the project were:

1) A report by Dr. Cherry and Golder Associates indicated that there was insufficient data to accurately describe the hydrogeologic environment. More observation wells were installed to the south of the quarry and additional information was collected by Morrison Beatty Limited. This additional information was used to prepare a

supplemental hydrogeologic report/5/. After reviewing this report, Golder Associates sent a letter to the City of Mississauga stating that they felt that sufficient information was available to characterize the hydrogeologic environment and that leachate migration should not seriously affect groundwater quality. It was also stated that the filling project should have no impact on the seepage area evident in some backyards south of the quarry/7/.

2) It was determined that ash leachate could be controlled by an underdrainage system to collect leachate and a clay cap on top of the ash fill to minimize prevent infiltration.

3) Field and laboratory testing showed the hydraulic conductivity of the shale to be low and the water quality to be poor. Ash leachate would not migrate rapidly through the shale and would not significantly affect the groundwater quality. Ash leachate was non-potable primarily due to dissolved salts, not due to heavy metal concentrations. The groundwater also contained high concentrations of dissolved salts.

4) An estimation of the expected volumes of ash production was used to determine the expected traffic volumes and hours of operation. Traffic due to ash haulage was estimated to be less than 10% of existing truck traffic and expected to cause no major traffic problems.

5) Noise levels were measured at several locations around the quarry and found to be greater than the expected noise levels due to the landfilling operation. It was concluded that noise generated by the landfilling operation should have no impact on the local residents.

6) The landfilling project would reclaim land that was currently unusable and produce land that would be a benefit both to those living near the quarry and the local environment.

7) Hydro's past experience with fly ash filling projects showed that they were capable of handling this project.

8) Domtar appeared ready and willing to comply with MOE requirements and was prepared to ensure that the landfill would be operated to meet MOE and City of Mississauga standards.

No conclusive findings that would call for rejection of the application were presented by any party.

2.4 Timetable

The approval process was lengthy. Hydro initially approached Domtar in 1978 with a proposal to fill the unused portion of their quarry with coal ash. Following the agreement

with Domtar, site investigations and preparation of the Domtar report began. The initial landfill application was filed with the MOE by Domtar on June 25, 1980, along with their report. It was hoped that approval would be granted so that filling could begin during the later part of 1980 or early 1981. A series of meetings and environmental board hearings followed in late 1980 and the early part of 1981. A supplemental report was submitted in April, 1981, to augment the data contained in the Domtar report. A provisional approval certificate was granted on August 18, 1981. Filling began on December 18, 1981, after the terms in the provisional certificate were met. The steps in the approval process described in the previous sections are summarized in Table IV.

2.5 Terms of Landfilling Certificate

A provisional waste disposal certificate for the project was granted to Domtar on August 18, 1981. This certificate contained conditions for groundwater, surface water, leachate, and dust monitoring that had to be met before and during the operation of the landfilling project. Provisions for reporting the amount of material deposited at the site, yearly progress reports, review of progress reports, and predictions of future site activity were also stated. Golder Associates were retained by Domtar to aid in the monitoring of ash compaction and to meet the Ministry's request that the project be overseen by an independent party.

Determination of the costs of long-term monitoring and leachate treatment also had to be estimated and a bond for this amount had to be submitted prior to the deposition of any coal ash at the site. Truck washing facilities had to be completed and the Provisional Certificate and the land title had to be registered at a Land Registry Office before any ash could be placed at the site. Extension of the approval beyond December 31, 1983, would be granted after the meeting of an environmental review board.

A copy of Provisional Waste Disposal Site Approval Certificate # A220113, granted to Domtar, is given in Appendix A.

3.0 SITE PREPARATION

Before landfilling with ash could begin, a number of tasks had to be completed as part of the site preparation. These preparation tasks are discussed briefly below.

3.1 Access Road Construction

The existing access road at the site was being used by the quarry for their general operating equipment and shale haulage using large, off-road Euclid trucks. This existing road entered the northwest end of the quarry and the ash hauling trucks would have had to travel a much longer distance to reach the filling area. This road also had several switchbacks that were difficult to manoeuvre in the long-box ash tractor trailer trucks. In order to avoid traffic problems, to reduce hazards to ash hauling trucks on this road, and to reduce the travel distance for the trucks hauling fly ash, it was decided to build an access ramp directly into

the filling area. This access road was constructed in the south end of the quarry and was used strictly for ash hauling.

An agreement between Domtar and Ontario Hydro stated that the latter would be responsible for supplying base coarse and aggregate required to construct the access road. Initially, it was desired to construct this ramp out of ash to further increase its utilization. The approval process for the landfilling certificate was quite lengthy and it was preferred to have this road ready for the filling operation once approval had been granted. The access road was therefore constructed of waste brick and shale from the site in order to limit the amount of material that would have to be imported. In order to avoid jeopardizing approval of the landfilling certificate, ash was not used for the access road construction.

The access road was constructed by filling in a small quarry west of the landfill area, blasting through the quarry rim and building a 250 m long ramp down into the quarry. The geometry of the quarry lead to a ramp slope of 8%, which was marginally acceptable for winter operation. Domtar was responsible for the construction of the access road including the relocation of all gas lines necessary for construction. A gas line supplying the plant had to be moved. Lighting for the road was also the responsibility of Domtar, however Ontario Hydro agreed to sell Domtar the necessary poles, cable and lights from its existing surplus inventory.

Both the old and new access road locations can be seen in Figure 8/8/.

3.2 Surface Water Control

If excess water were to enter the quarry, the ash could become saturated. Operation of equipment on top of saturated fly ash can be difficult because the shear strength of the ash is greatly reduced by saturation, causing deep ruts to form easily so that equipment sinks into the ash and becomes stuck. Also, the required compaction for a structural fill can not be achieved if there is excess water in the ash. In order to control surface water at the quarry, drainage ditches, surface grading and deflection berms were used to divert surface water from entering the quarry or the ash cells. A drainage ditch was constructed parallel to a surface water deflection berm along the west quarry rim in order to prevent surface runoff from entering the quarry from the north and west/3/. Surface grading and a short deflection berm along the northeast rim of the first bench level were used together to divert runoff from the northeast into Mary Fix Creek.

Berms for surface water control were designed to be about 1.2 m in height to discourage vehicle traffic from crossing them, and about 1.8 m wide at the crest to facilitate grass cutting. The design sideslopes were suggested to be about 2:1 horizontal to vertical although this slope may have been modified to accommodate grass cutting equipment. Some of the material used to construct the surface water deflection berms came from the debris clean-up of the quarry floor.

Surface water control within the quarry was also achieved by the use of low permeability berms. Berms were constructed around each of the ash cells in order to prevent fresh water runoff generated within the quarry from entering the cells. Fresh water was kept from entering the ash cells so that it could be collected and immediately discharged into Mary Fix Creek. This fresh water was collected in fresh water sumps and pumped into the creek.

The locations of the drainage ditch and deflection berms can be seen in Figure 9/3/.

3.3 Debris Clean-up

The clean-up and quarry floor preparation prior to filling was the responsibility of Ontario Hydro. Loose talus, weathered shale and a large pond had accumulated within the quarry in the area of the proposed filling operation. Before any work could begin, the pond had to be pumped from the quarry. In order to provide a suitable hard base for the compaction of the fly ash to structural fill standards and to ensure that there was no compressible material below the ash that could cause differential settlement, the bottom of the quarry had to be cleaned up. This involved the scraping and either removal or compaction of loose material and weathered shale to provide a stable, graded working surface. This graded surface was important to ensure proper leachate collection at the bottom of the ash cells which were to be placed directly on this surface.

The debris clean-up process took several months to complete and was quite labour intensive. This was partly due to the fact that frequent heavy rainstorms inundated the quarry. The control of water entering the quarry was difficult. Much of the debris from the clean-up was too wet to use for any part of the quarry preparation, however some of it was used for construction of the surface water deflection berms/3/.

3.4 Underdrainage

The design of underdrainage to control leachate migration was the responsibility of Hydro. Underdrains were deemed necessary for the landfill to provide a means of controlling leachate migration from the completed landfill, to control the expected rise in the water table during landfilling, and to collect water that could be recycled from a sump and used for compaction and dust control. The principal purpose of these drains however was to act a part of a contingency plan. The plan was to control leachate migration from the site by pumping water from the sump, thereby lowering the local groundwater table and causing flow into the ash area from the surrounding land.

An initial design for the underdrainage system was prepared by OHRD and forwarded to Morrison Beatty Limited. The design was reviewed, slightly modified, and returned to Ontario Hydro. This amended design was then forwarded to Golder Associates for review. They agreed in principal to the proposed design, however, they expressed some concern about the suitability of the granular filter material (bottom ash) that was proposed for use around the drainage pipes. Ontario Hydro acknowledged this concern and agreed that Golder Associates should sample and check the suitability of the filter material against drain

installation was being completed. A discussion of the details of this drainage system is given below.

For the drainage system, plastic PVC pipe was chosen due to its corrosion resistance and to avoid influencing analyses of ground water quality. Schedule 80 pipe was chosen to ensure pipe strength and durability and to limit pipe deformations that could cause constriction of the openings in the perforated pipe sections. Ontario Hydro, Morrison Beatty Limited, and Golder Associates all agreed that this was a suitable pipe selection.

Underdrainage was initially constructed in each cell prior to the commencement of cell filling. In each cell, it took the form of a herringbone configuration of 10 cm diameter piping spaced at 20 m intervals and aligned parallel to the slope of the quarry floor. The pipe perforations were approximately 3 mm in diameter with approximately 24 perforations per 30 cm length of pipe. The collection system was designed by assuming a fly ash permeability of 1×10^{-5} cm/sec, a value that was based on previous studies. The "relief drain formula", with an estimated flux of 0.5 L/s/ha over the area of ash fill, was used to determine pipe spacings. These 10 cm pipes were connected to larger 15 cm diameter unperforated main collector pipes. These collectors carried water to the main leachate sump at the south end of the quarry. Figure 10 /8/ shows the design configuration for this drainage system.

All of the pipes were initially designed to be placed in trenches at least 30 cm below the quarry floor. Initially it was thought that the trenches could be made using a bulldozer with a ripper tooth attachment. This proved to be ineffective due to the strength of the rock. Trenches for the pipes had to excavated in the shale quarry bottom by drilling, blasting and scraping with a bulldozer equipped with a ripper tooth. This method was used for the initial cells but was laborious and costly. In later cells, ash was placed on the quarry floor and trenches were dug into the ash to place the drains. The reason for initially placing the pipes in rock trenches was to protect them from landfilling equipment and winter snow clearing operations. This practice was deemed by Morrison Beatty Limited to have no significant effect on the performance of the drainage system. A well graded fine to coarse asphalt sand was chosen as a bedding and filter material for the perforated pipe by using standard filter criteria. Bottom ash did not meet filter requirements necessary for this application. The collector pipes were interconnected and all drained to the main leachate sump. The leachate sump was located at the south end in the lowest point of the quarry floor, as shown in Figure 10.

3.5 Sumps

The installation of sumps for water control was the responsibility of Ontario Hydro. The sumps used at the site were both temporary and long term. The temporary sumps were used for the control of fresh water that had entered the quarry. This meant that any water that entered the quarry and did not come into contact with the ash could be collected in these temporary sumps and discharged directly to Mary Fix Creek. The long term sump was built in the lowest part of the quarry as part of a contingency plan to control leachate escape from the site and seepage problems in a nearby residential area. It accepted water from the

main collector pipes of the ash cell underdrainage systems and provided water for compaction and dust control.

The main leachate sump was constructed of 75 cm diameter bitumen coated corrugated steel culvert pipe installed vertically to serve as a well. Using this type of sump construction, the well could be extended as the fill level rose. The configuration of this well and its connection to the underdrainage system is shown in Figure 11 /9/. Pea gravel was used for the bedding and backfill of this well and a filter system consisting of an asphalt sand and a medium to coarse sand with 20% fine gravel was used to make the transition from fly ash to pea gravel. The purpose of this sump was to collect the fly ash leachate and to provide a well from which water could be recycled for use in compaction and dust control.

Secondary 90 cm diameter sumps were installed in low points of the landfilling area to collect fresh water that entered the quarry. This included rainwater runoff from capped ash cells. The water collected in these sumps was uncontaminated by ash leachate and could be discharged directly into Mary Fix Creek. The fresh water sumps were located in cells 2, 3, and 6 while filling was ongoing in other cells. Once filling with ash began in each of these cells, the sumps were no longer used for fresh water collection and they were sealed. A large fresh water sump was developed in the north end of cell 6 where it will remain until the surface of the landfill is sloped towards Mary Fix Creek.

3.6 Cell Berms

The landfilling of ash at the quarry was done in a series of 7 small "cells" in order to reduce the working area of exposed fly ash. This was considered necessary for operation because not enough ash was available to raise the entire quarry floor at a rate greater than the expected water table rise due to precipitation. Using smaller cells allowed the filling rate to exceed the water table rise and maintain a dry, stable working surface. The reduced working area also allowed compaction monitoring to be done on a smaller, controlled area, ensuring that the fill was being compacted to the required density.

Using cells also meant that only a small surface area of ash would be exposed to physical weathering and be a possible source for dusting. Water was restricted from entering the compacted ash by the use of a clay cap and cell berms. The control of water entering the ash meant that the majority of rain water could be discharged to Mary Fix Creek, and only a small amount of ash leachate had to be handled. Upon completion of filling, each cell was capped with 15 to 20 cm of clay in order to reduce infiltration. This surface cap was sloped to direct water from the cell top to the nearest clean water sump. The cell numbers and configurations can be seen in Figure 5.

The berms separating the cells were constructed of clay and waste shale and increased in height as the ash was added. A cross section, Figure 12/10/, through a cell shows this process. Much of the clay used to construct these cell berms and caps came from overburden stripped from other areas of the quarry, outside the landfill area, where shale

quarrying was ongoing. Additional material also came from construction excavations in the area.

3.7 Truck Cleaning

In order to prevent the tracking of fly ash from the site, a truck cleaning facility was necessary to remove ash from the trucks. Since ash was delivered to the site in a dampened state and because the ash was watered to prevent dusting, it had a tendency to stick to truck tires and parts of the truck body. If this damp ash were to be tracked onto the roads and then dry out, a serious dusting problem could develop. Since Ontario Hydro was responsible for the ash hauling to the site, Ontario Hydro was also responsible for the truck cleaning station.

Removal of ash that had adhered to the bodies and tires of the trucks leaving the quarry was done by a series of methods. A "rumble strip" was constructed of railway rails placed perpendicular to the direction of travel of the truck and was used to shake loose ash from the truck as it was leaving the quarry. A truck wash station was also built so that ash could be water-jetted from the trucks in the summer and a "steam jenny" was tried to remove ash from the trucks in the winter. Steam proved to be dangerous, however, as it also caused icing of the trucks in cold weather. The "steam jenny" was later operated as a compressed air system to blow the ash from the trucks. This proved to be a successful way of removing ash from the trucks and their boxes.

4.0 SITE OPERATION - LANDFILLING

The filling project began December 18, 1981, almost a year and a half after the application was submitted. The final load of fly ash was placed on December 30, 1986, five years after filling started. Construction of the seal layer continued throughout 1987-88, due to difficulties finding suitable material. Soil for construction of the erosion cover is currently be stockpiled at the site. The expected completion date of the cover will be a function of the availability of suitable material. The final completion date including contouring and grading is expected to be sometime in 1991 or 1992.

Initial site operating guidelines were suggested by Ontario Hydro at the EAB hearings. These guidelines were based upon Ontario Hydro's past experience landfilling with fly ash. This experience included filling at the Ambler Courtney Site, Oakridge Park, Birchwood Park, and Booth Quarry. The actual site operation was controlled by Domtar and monitored by Golder Associates, the geotechnical consulting company hired by Domtar as a requirement of the Landfilling Certificate.

Most of Ontario Hydro's past landfilling experience was with "dumping operations" and not with the use of fly ash as a structural fill. They had an idea of how the material should be handled and placed, but it took time to implement and refine these practices. Due to the differences in behaviour between natural soils and fly ash, there was a learning period during the initial stages of the filling operation where those working with the ash became

familiar with its distinct characteristics. Below is a discussion of some of the technical and operational aspects involved with the filling of the quarry.

4.1 Ash Quantity Planning

The quantity of ash produced annually by the Lakeview TGS and R.L. Hearn TGS was estimated from previous ash production. The actual quantities of ash that would be produced was difficult to estimate because the generating stations were not base loaded, they were only operated during peak demand periods. Ontario Hydro was required to provide Domtar with a forecast of ash production at 6 month intervals throughout the life of the project. The estimates of ash production made in 1980 and 1981 are seen in Figure 13/3/ which also shows the actual quantities of ash deposited at the site for comparison.

4.2 Filling Sequence

Prior to filling, plans were made to divide the quarry floor into 7 individual cells as shown in Figure 5. Cells were generally designed and operated with an exposed surface area of one hectare during the winter when ash production was highest. This area was reduced to approximately 0.5 hectares during the summer when ash production was lower and the potential for dusting was great due to hot dry conditions. The quarry floor was also divided into cells to allow the fill level to rise by at least 2.5 m per year. This rate of fill level increase was chosen because the expected annual rate of groundwater table recovery was 2.2 m per year. The generating stations did not produce sufficient ash to raise the entire quarry floor at the desired rate. Each cell was separated from the others by the construction of impermeable cell berms.

The cell sizes were chosen to optimize the filling operation and limit the working area to prevent dusting. Site preparation for cells 1 through 5, which included cell berm and underdrainage construction, was completed by December 15, 1981. Although the cells were numbered, filling did not occur in any specific order. The actual filling order was a function of ash production, cell geometry, and constraints on cell accessing with equipment. Difficulties occasionally occurred when more ash was produced than could fit in the current working cell, yet there was not enough ash to start a new cell. Cells were often subdivided or joined in order to improve the operating efficiency of the project or reduce the exposed surface area.

In the first 3 years of landfilling, ash placement was concentrated in cells 1 through 5, although no filling was done in cell 4. Cells 6 and 7 were later filled. Figure 14 /3/ shows 2 different cross sections through the quarry, illustrating how the ash was placed in layers and how adjoining cells were sometimes combined. During the 1983 operating year the maximum fill level (117 m a.s.l) was staked to ensure that the maximum fill level set by the MOE was not exceeded. The actual filling sequence for all of the cells is illustrated in Figure 15.

Aerial photographs of the site were also taken, from the north, looking south, several times during the landfilling operation. Figure 16 shows the quarry prior to pit preparation or construction of the access road. Figure 17 shows the quarry as of July, 1983, where the access road, some existing cell berms and fresh water sumps can be observed. Figure 18 shows the quarry in October, 1985. A clay covering can be observed on some of the cells in this figure. Figure 19 shows the quarry in summer, 1987. This figure shows a clay covering on most of the cells, the clean water sump in the north end of cell 6, and the stockpiles of material to be used to construct a protective cover.

4.3 Haulage, Spreading and Compaction Equipment (Selection/ Operation)

Ontario Hydro's previous experience with ash landfilling, and published reports by other agencies, confirmed that conventional construction equipment could be used for the haulage, placement and compaction of coal ash.

For haulage, conventional tractor trailer trucks with aluminum boxes were used. The boxes on these trucks were enlarged to 39 cubic metres by increasing the box sides to accommodate the transportation of more ash, which has a lower specific gravity than normal construction materials /3/. These boxes were also lined with teflon to prevent the adhesion or freezing of the dampened ash to rough truck box sides and allow for easier dumping /3/. The boxes had closed tops and hinged doors for loading. The ash was totally enclosed to maximize in-transit environmental acceptance.

The equipment necessary for the compaction and spreading of the fly ash and other associated earthworks was provided and maintained by Ontario Hydro. Domtar was responsible for supplying the necessary fuel and operators. Spreading and compaction of the fly ash was done using conventional construction equipment. D8 or D9 dozers with tracks were used to spread the ash in 25 to 30 cm lifts and 20 ton smooth drum vibratory rollers were used to compact the ash. Rubber tyred dozers were tried, but they were not effective on the ash surface. At times of high ash production, 2-3 dozers and 3 compactors worked to place and compact the ash. In the early stages of the project, test areas were used to establish the number of passes required by the compactor to achieve the desired level of compaction. This method and equipment had been used and found satisfactory by agencies in the U.S. that have used fly ash as a structural fill material.

The cell structure of the filling area provided logistical problems with equipment operation. Equipment was normally confined to a specific cell because of the differences in elevation between adjacent cells and the berms separating the cells. This meant that extra equipment was necessary when filling was on-going in more than one cell.

Another operating difficulty that was noted to be a direct result of working with fly ash was the abrasive action of the ash on the equipment. Fly ash is made up of silt-sized spherical particles of silica, making them very hard, and abrasive. Their small size allowed them to work their way into small openings in the equipment and cause significant problems. Wear

on bulldozer tracks was 130% in one year, brakes had to be changed more frequently and oil and air filters needed changing monthly/3/.

4.4 Compaction Control and Testing

Past experience with fly ash had shown that it could be spread and compacted to desired densities using standard construction equipment. For most of the fly ash delivered to the site the standard Proctor maximum dry density averaged 1240 kg/m^3 at an optimum moisture content of about 27%/3/. The compaction criteria set for the fly ash at the onset of the filling program was 95% of standard Proctor maximum dry density, with uniformity across the site. This was to ensure suitable bearing capacity and reduce the potential for differential settlement of future structures at the site.

A test section showed that two passes of the compactor was necessary to achieve the desired density at 25% moisture content. At a water content of 21%, six passes were required to reach the desired density. Moisture content of ash delivered to the site was between 15% and 20%. For this moisture range, it was found that eight passes with the compactor were necessary to achieve the required density. It was important to ensure that adequate and uniform compaction was being achieved. This was done by instituting a rigorous compaction testing program.

Compaction control was aided by the small filling areas that were being used to control dusting. These areas were ideal for carrying out uniform testing, in a grid-like arrangement, for compaction standards. Domtar was responsible for ensuring that the material was sufficiently compacted to meet the City's guidelines for future land use and satisfying the monitoring and reporting requirements stated in the Provisional Waste Disposal Site Certificate. To assist with the compaction control and testing, Domtar hired Golder Associates. Ontario Hydro also provided Domtar with some insight into compaction control and testing throughout the project.

4.4.1 Density Measurement Method

For in-situ density measurements of the ash, a study was done by Golder Associates to determine the best possible method. This study examined balloon densimeters, shelby tube samples and nuclear density gauges. The shelby tube samples and the balloon densimeters were able to give reasonably accurate density measurements in the laboratory although there was a large scatter in the data /3/. Initially it was found that the nuclear density gauge gave incorrect density and moisture content readings due to the chemistry of the ash. The readings, however, were more repeatable and consistent. It was found that by altering the internal calibration program of the nuclear gauge, it could be used to get accurate readings.

The nuclear density gauge is fast, easy to use, and is the instrument preferred for the measurement of in-situ soil density and moisture content by most consulting firms. A nuclear gauge was obtained by Domtar, calibrated by Golder Associates, and designated for use exclusively in fly ash. In some cases different coal types and station loading caused ash with

slightly different chemistries to be produced. For some ash, the nuclear density gauge was ineffective and laboratory compaction box tests or balloon apparatus had to be used to determine densities and oven dry tests were used to calculate moisture contents. Overall, as long as the ash chemistry was consistent, the nuclear gauge performed well.

4.4.2 Monitoring

Initial monitoring of the in situ densities of the compacted ash indicated that the desired density was not being achieved. Instead of the target value of 95% of Standard Proctor maximum dry density, a value of only about 90% was being achieved. This was initially thought to be a serious setback to the filling project as the ash might not be approved as a structural fill. Visual observations of trucks travelling across the ash, however, indicated that the ash was quite dense. A decision was made to perform plate load tests on the ash in order to estimate the settlement of a light structure constructed on the site.

4.4.3 Plate Load Tests

Plate load tests were carried out at a number of locations in the compacted fly ash as shown in Figure 20/12/ using a typical set-up as shown in Figure 21 /13/. The majority of the tests were conducted and monitored by qualified personnel from Domtar, Ontario Hydro, and Golder Associates. Initial plate load testing was done in January and February, 1982. The results of these plate load tests indicated that tolerable settlements (less than 15 mm) would occur for foundation loadings of 140 kPa. Because the load test results might have been influenced by the ground being frozen and the short duration of the test, it was recommended that more tests be done during warmer weather and for a longer duration.

A long term plate load test was set up on February 8, 1982, and continued until October 31, 1982. This test was done at a loading of 240 kPa, twice the expected foundation loadings for the structures planned for the site, and less than 5 mm of settlement was observed. The majority of this settlement occurred shortly after load application. These settlements are given in Table V/14/. It was stated by Golder Associates that settlements of this magnitude are of little significance to residential buildings/14/.

Further short term plate load tests were also done in 1982 at various locations in the ash fill. These tests were conducted on fly ash of different in situ densities and at loads higher than expected for residential use. The results of these tests are summarized on Table VI/3/. These tests showed that the compacted fly ash would be able to support the expected structural loads, at a density as low as 85% of standard Proctor maximum dry density, with a minimum amount of settlement.

4.4.4 Density Requirements

As a result of these tests and the visual observations of ash performance, the target density of the ash was lowered to 90% of standard Proctor maximum dry density. This density was achieved throughout the project with few difficulties.

4.5 Dust Control

The control of fugitive dust from all operating procedures was a major concern. Ontario Hydro was responsible for any ash escape as a result of the hauling of the ash from the generating station to the quarry. Control of ash escape from the trucks was done by conditioning the ash to a moisture content of approximately 15% at the generating stations. The ash was then transported in covered truck boxes to the site. Leaky tailgates on the trucks were identified as possible sources of ash escape and care was taken to ensure that tailgates were properly sealed. Ash that had adhered to truck bodies and truck tires while in the quarry was removed by the combination of a "rumble strip" and a truck washing facility before trucks left the quarry to return to the generating station. Water was used to wash trucks in the summer and compressed air was used during the winter. Steam was tried, however, it would freeze and cause a driving hazard for the trucks. The control of dusting at the quarry was the responsibility of Domtar. Three specific methods were used to control fugitive dust at the quarry.

The first method was to keep the size of the working area small so that only a limited amount of ash was exposed to physical weathering. The sizes ranged from one hectare in the winter when ash production was high to one-half hectare in the summer when ash production was low and the weather was hot and dry. This was done by subdividing the cells with small clay berms.

The second method used to control dust escape from the site was ash wetting. Ash was delivered to the site at about 15% moisture content and a 13,600 litre capacity water spray truck was constantly at the site to spray the ash if it dried out. Water was recycled from the leachate sump to use for dust control. A back-up water truck was available on short notice from Lakeview TGS as part of a contingency plan to control dusting. The watering system was quite effective during warmer weather, but ineffectual in cold weather. During cold weather the ash "freeze-dried" and caused some severe dusting problems. Waste oil, like that used to control dust on gravel roads, was tried on one occasion. Snow-making was tried experimentally and found to be effective. The night watchman was required to inspect the ash regularly during off hours and call in a water truck if dusting conditions were developing.

The third method used to control dusting was to cover the areas where filling was complete with a layer of clay or glacial till. A 15-25 cm layer of material was placed over the compacted ash to prevent dusting. This layer was graded towards the fresh water sump so that there would be no ponding on the ash and the runoff could be discharged directly to Mary Fix Creek. This cover was later removed and stockpiled if more ash was to be added to the cell. The cover could not be surfaced with ash because it might cause a "bathtub" effect, resulting in a pocket of saturated ash, and causing equipment operation problems.

A water pumping and sprinkler system to control dusting was proposed and some design work was done during the 1982 operating year. The system was not built, however, as it

was later determined not to be worthwhile. In general terms, dust control was maintained by adopting the first 3 methods.

4.6 Control of Water in Ash

Ash was to be delivered to the site at a water content of 15%, however, the method used to wet the ash at the generating station was not perfect. Moistening of the ash at the generating station was done by passing dry ash through a dustless unloader. In the centre of the unloader, and parallel to the long axis, was a spray bar. The volume of the water from this spray bar was not metered and was added qualitatively. Also, the walls of the unloader were not allowed to become wetted or the unloader could become plugged. This meant that during the passage of the first and last portions of ash through the dampener, the water was turned off and the ash passed through dry. Thus, the distribution of moisture throughout the ash was not ideal and no mixing of the ash took place once it was loaded in the trucks for transport. At the site, the ash was immediately spread and compacted and thus little time was available for the conditioning of moisture within the ash.

The height of the ash in the storage silos also had an effect on the wetting of the ash. The silos were often allowed to fill to near capacity while efforts were made to market the ash as a concrete additive. If no market could be found, the ash would be drawn down from the silo and utilized at the landfill. The feed pressure from the gravity drawdown of a nearly full silo is greater than that from a nearly empty silo. There was a high likelihood of pressure-feeding the unloader causing reduced wetting of the ash. This resulted in a low water content for the ash when compared with ash that was not "forced" through the unloader.

The control of water content in the ash was considered to be important to the disposal project for several reasons. A low ash moisture content reduces haulage costs but causes difficulties in compaction and dust control. A high moisture content facilitates compaction and dust control but can cause cold weather handling problems and increase haulage costs. Ideally, a consistent moisture content throughout the ash was desired in order to ensure consistent handling procedures, ease of placement and a uniform compacted density. Inconsistent moisture contents can cause handling problems such as dusting and lead to a fill that is unevenly compacted. This could lead to differential settlements which could adversely affect future development at the site/15/.

To examine the uniformity and consistency of the moisture content of the fly ash entering the quarry, a sampling and testing program was instituted at the site in February, 1982. For three days, samples were taken from almost every truck load of fly ash entering the quarry. For each truck load, three samples were taken at random from the ash after it was emptied from the truck. These samples were then oven-dried overnight at a temperature of 105 °C in order to determine their "as-delivered" moisture content. A total of 271 samples were taken over this three day period so that a statistical analysis of the ash moisture content could be conducted/15/.

From the analysis it was found that the average moisture content varied from 14.8% to 20.1% throughout the ash. An example of the range of moisture contents measured can be seen in Table VII/15/. This variability could have been controlled by different wetting methods such as, metering of the amount of water added to the ash, mixing wetted ash, or allowing time for the moisture to be distributed within the ash. None of these methods were used. Nevertheless, density monitoring and plate load tests indicated that the ash was well compacted and should support the required foundation loads with negligible differential settlement.

4.7 Groundwater Monitoring

For the purpose of groundwater monitoring, approximately 33 wells were placed both up gradient and down gradient at the site. Sampling and testing of the water from these wells was done on a regular basis. Up-gradient wells were sampled and tested annually, wells installed within the ash were sampled and tested four times annually, and the down-gradient wells were sampled and tested three times annually. Sampling and testing of the water from the wells was carried out by staff from the Chemical Research Department of the OHRD. Wells were bailed-down before sampling to ensure that only groundwater was being sampled. Piezometric head readings were also carried out six times annually to determine any changes in the water table. The locations of the monitoring wells and the sumps can be seen in Figure 5/6/.

The chemical analysis of the well water focused on changes in major ion chemistry. The concentrations of boron and strontium were also studied as these two elements are considered to be indicator components of fly ash leachate. Both field-filtered and laboratory-filtered water samples were analyzed and gave similar results. Aside from minor shifts in major ion chemistry that were not attributed to fly ash placement, and some temporal variations in water chemistry, there were no observable adverse effects on groundwater quality due to the placement of the ash.

Samples of water were also taken from the main leachate sump in order to try to get an indication of the quality of the leachate being produced. The results of chemical analyses on these samples were ambiguous, however, because of the ions from the galvanized metal pipe used to construct the sump, and the influence of local groundwater that had permeated the ash and was being collected by the leachate collection system. Therefore, determination of the leachate quality from water samples taken from the sump was tenuous.

Monitoring of the piezometric levels was done to determine the rate of increase of the groundwater table. Initially it was thought that precipitation would cause the groundwater table to rise at a rate of about 2.2 m/year/4/. This increase rate was not observed and the piezometric levels remained fairly constant throughout the project life. This indicated that the surface water control methods and ash underdrainage system were functioning properly. In 1989 it was observed that the piezometric levels at some wells had risen above the level of the sump. It was recommended that the level of the sump be increased to prevent ponding of water at the surface/11/. The sump has since been extended and rehabilitated.

Due to the length of the project, some rehabilitation work had to be done on the main leachate sump during the 1989 operating year to ensure that it functioned properly in the future. Water samples taken from the sump during previous years indicated that the bitumen coated corrugated pipe could be corroding. Therefore, PVC pipe was placed inside the corrugated pipe and held in place by grouting the annulus between the two pipes. The height of the sump was also increased to prevent a ponding problem that was foreseen.

Another problem with the monitoring wells was also encountered due to the length of the project. Due to the fact that the project was in a densely populated area, where other construction projects were taking place, many of the wells were damaged or destroyed, and had to be replaced. Four down-gradient piezometers (Hs, Hi, Is, Ii) were destroyed by local construction in 1982, but replaced by two new wells in 1983 along the same flow path. Prior to well replacement, two nearby wells (Fs, Fd) were used as sampling points. Two upstream wells (5A(s), 5B(d)) that had been destroyed by fire were replaced at approximately the same time. In mid-1985 three more wells (Es, Ei, Ed-2) were destroyed by local construction. These wells were replaced in late-1985 by boreholes Ed-85 and Es-85. Prior to well replacement, two nearby wells (Fs, Fd) were again used as sampling points to avoid the loss of valuable information. During the 1986/87 sampling period piezometer 5A was damaged and later replaced in February of 1987. During the 1987/88 period 6 piezometers (1, 2A, 2B, 6, 7, 9) were damaged by local construction. During the summer of 1989, 7 new wells were installed to replace those that were previously destroyed. Construction of roads and buildings outside of the quarry area was the primary cause of well damage.

4.8 Surface Water Monitoring

Surface water monitoring was conducted at the site for several reasons. Measurement of the base flow rate in Mary Fix Creek was done in order to determine when leachate might be discharged into the creek, if necessary, and still have elemental levels meet the MOE standards. Sampling of Mary Fix Creek was carried out both upstream and downstream of the fill area from four different points: the C.P. Overpass (CPO), the South Property Fence (SPO), the Dundas Street Culvert (DSC), and the Paisley Street Bridge. These locations are shown on Figure 5/6/. A problem with vandalism of flow measuring devices initially hindered the surface water monitoring program, however, this was overcome by using portable monitoring equipment.

Sampling of surface water was not done on a regular basis like the groundwater monitoring. Instead, surface water sampling was done during periods of different flow in the creek. For example, sampling was done during peak flow (April), base flow (June), and intermediate flow (October) conditions, however, the actual flow conditions encountered did not necessarily occur at the same time each year. Flow conditions had to be considered in the monitoring program as they affected the analysis of water quality. Sampling and recording of the flow conditions was done 2 to 3 times per year over the life of the project.

Throughout the entire project no leachate was discharged into Mary Fix Creek and therefore no change in water quality was expected. Changes in water quality, however, were

observed in the creek at several times throughout the project lifetime. Elevated levels of strontium and boron (fly ash leachate indicators) were observed in late 1986 through to 1989 and seemed to indicate that some fly ash leachate was entering the creek. The exact cause of this contamination could not be accurately determined and concentrations fluctuated arbitrarily. Suggestions that the contamination could be from surface runoff or groundwater base flow to the creek could not be proven. It was also suggested that the contamination could be coming from other sources upstream of the quarry. The levels of contaminants were still quite low and did not warrant further examination of the hydrogeologic regime. Careful monitoring of the creek, runoff retention ponds, and sump was suggested by Golder Associates to try to determine the source of this contamination/10/.

4.9 Dust Monitoring

Dust monitoring was conducted by following a program approved by the Director of the Environmental Approvals Branch of the MOE. The MOE has limits on the amount of dust that people should be exposed to for given time periods and it was specified that these levels should not be exceeded. The monitoring program included measurement of dust levels by two different methods. Dust fall levels from these two methods were then included as an appendix to each annual report submitted to the MOE by Domtar.

Dust sampling jars placed at various locations around the quarry were one method of measuring the amount of fugitive dust escaping from the site. Five jars were located close to the residential areas, downwind of the quarry, as seen in Figure 5/6/. The dust fall jars were mounted on poles 6 to 12 feet above the ground in order to avoid influence from blowing ground dust and to protect them from vandalism. Dust fall samples from monitoring jars were collected monthly and taken for analysis. The jars were prone to damage by vandalism and contamination with bird droppings and other organic materials, however, they still provided valuable dust fall information.

A high volume sampler was also used to collect dust samples. The location of the high volume sampler is also shown in Figure 5/6/. This sampler was operated during hot or dry periods when large dust volume emissions were expected. During these periods it was operated continuously, with the filters being changed every four days and sent for analysis.

The dust fall measurements from these monitoring stations were compared to MOE standards for monthly and yearly allowable dust fall. These standards are given as 20 tons/mile^2/30 days and 13 tons/mile^2/30 days, respectively/3/. The majority of the time the measured dust fall was below MOE levels, however, on several occasions these levels were exceeded. These high levels occurred when dust falls were also quite high in areas away from the quarry. Therefore the MOE was not overly concerned with these few instances.

An investigation was done in order to determine whether it was fly ash dust or some other (shale and road) dust that was being collected by the sampling devices. Due to the similar chemical compositions of coal ash and shale, chemical analysis could not be used to distinguish between the dust types. A scanning electron microscope was used to aid in the

analysis of the particles collected from the dust measuring devices to distinguish ash dust from other dust. It was thought that ash dust was round while shale dust was angular. This was not always the case, however, and this method was not wholly successful. It was estimated that fly ash made up between 5% and 80% of the total ash collected by the sample methods.

4.10 Pond Ash

Ash filling at the site was primarily done using wetted fly ash from the dry ash collection facilities at the generating stations. In several instances, however, pond ash was deposited at the site. Pond ash is the fine-grained particles filtered from the water used to "jet" bottom ash from the boiler of the generating unit. It has a very high water content as it is stored in a retention pond.

Ash of this type was trucked to the landfill site, allowed to free drain, and then spread and compacted like normal fly ash. Density measurements were then conducted on the ash to see if it was at the required density. If it was below the desired density, it would be allowed to settle for a period of time so that water could rise to the surface and evaporate. The ash was then re-compacted and the in situ density was again measured. If the density was still below the required value, the ash was again allowed to dry for a period of time and then re-compacted. This cycle of compaction, density testing, drying, and re-compaction was continued until the ash achieved the required density.

When dried too much, pond ash could cause serious dusting problems due to the segregation of finer particles from the ash. Pond ash dries by consolidation and the percolation of water to the surface. As water moves upwards through the ash it carries the finer particles to the surface. When dried, these particles could easily become airborne. This problem required special consideration.

4.11 Ash Transportation

The transportation of ash from the generating stations to the quarry was the responsibility of Ontario Hydro. Trucks used for the transportation of ash from the generating stations to the site were normal tractor trailer trucks. The boxes of the trucks were enlarged to 39 cubic metres to allow the transportation of greater volumes of ash which has a lower specific gravity than natural soils. These boxes were lined with teflon to prevent ash from sticking to the box sides and totally enclosed to minimize ash escape.

The determination of the effects of the volume, noise, hours of operation and route of truck traffic on the local residents were all concerns expressed at the EAB hearings. During peak filling periods up to 80 truckloads of ash were delivered to the quarry site daily. Truck traffic from this hauling was estimated to be less than 10% of the current truck traffic along the trucking route, and was estimated to have little effect on overall traffic flow. Since truck traffic would be the heaviest during the winter months while residential windows were closed, the noise from the trucks was not expected to significantly bother the residents. The

trucks were also limited to hauling during the day, between 7:00 am and 4:00 pm, Monday to Friday, so as not to annoy local residents. Some provisions were made for after hours and weekend hauling when ash production was high.

Ash hauling trucks entered the quarry from the southwest on an access road built exclusively for the landfilling program. The trucks then deposited their load in the current working cell and proceeded over the rumble strip and through the truck wash before leaving Domtar property. Spreading of the ash was not done by "tailgating" with the trucks, as this could lead to excessive dust production and can be dangerous to the driver if ash adheres to the truck box and tips the truck. Tailgating is when the trucks raise their boxes up, reverse rapidly, and brake suddenly to cause the tailgate to swing and to bang the ash from the truck box.

4.12 Underdrainage Expansion

The underdrainage system was installed on an as-needed basis, before filling of designated areas of the quarry. When filling initially started, the underdrainage systems in cells 2 and 3 were not connected to the main collector pipes leading to the leachate sump. Instead, the underdrainage in these cells was connected to 2 separate 90 cm diameter wells that were being used for fresh water sumps. These cells were later connected to the pipes leading to the leachate sump. An initial attempt to connect cell 3 to the main system was unsuccessful due to high water head. It was later connected when the head dropped. Poor connection of cell 5 to the main system was observed from "washout" during the 1982 operating year. This connection was later excavated and improved.

During the underdrainage expansion, it was noted that the ash was difficult to excavate and would stand up vertically in deep unsupported cuts. This was likely due to pozzolonic reactions within the ash. Vertical faces stood unsupported for extended periods of time during excavations for underdrainage expansion.

4.13 Temporary Cover

Whenever a cell was filled to a specified level, filling would normally commence in adjacent cells. In order to prevent excessive dusting from the inactive cell, a temporary cover was placed over the ash. This protective cap consisted of 15 to 25 cm of compacted clay or other impermeable material. The cap was sloped towards the area containing the clean water sump so that it would drain freely and limit infiltration into the ash. This clean water could then be discharged directly to Mary Fix Creek. This temporary cap served to reduce dusting and to limit infiltration into the ash on a short term basis, and provide a water management system by controlling the quantity of leachate contaminated water.

This cap was then removed from the top of the cell when more ash was to be added. The material from the cap was stockpiled and reused until it became too contaminated with ash to be any good. The cap could not be left on the cell or it might cause a perched water table and saturate the ash that was placed on top of it. Saturated ash is not a good working platform for heavy equipment because its shear strength is low and equipment can sink into

the ash. One incident occurred where a dozer sunk in up to its doors. Excavation of the area showed that the temporary clay cover had not been removed. It was removed and the area was refilled.

5.0 SITE OPERATION - CLOSE OUT

The close out of the quarry is an important part of the landfilling operation. MOE standards for landfill closure, and the specific requirements set out for this site had to be met. A hydraulic cap, 1 m thick, had to be placed over the ash, and then covered by a 1m thick protective soil layer that would qualify as a structural fill. The site also had to be "self-managing", so a third layer of fill was to be placed over the ash. This layer was to be contoured to allow drainage into Mary Fix Creek and seeded with grass to prevent erosion. Placement of these layers had to follow strict quality controls to meet MOE standards. The following sections describe the close out requirements and the close out operation.

5.1 Environmental Requirements and Design

The stipulations for close out of the Domtar (Canada Brick) quarry required that the site be "self-managing". This meant that the landfill must be sealed with an impermeable cap and then covered with a sloping protective layer of soil and vegetation. A post-filling groundwater and surface water monitoring program also had to be established. The seal layer was designed to limit surface water infiltration into the ash and therefore restrict the amount of leachate being produced. Groundwater quality and piezometric levels were monitored to ensure that leachate migration was minimal. Surface water monitoring was specified to ensure that surface watercourses were not being affected by run-off from the site. Each of these three aspects of close out is discussed below.

The seal layer was designed with two objectives in mind. These objectives included limiting infiltration into the ash to the horizontal groundwater flux, and controlling the upward migration of leachate. The seal layer was intended to protect future on-site and adjacent land-use activities from exposure to contaminants derived from the ash. The initial design for the cover system specified that a drainage blanket be placed on top of the ash and that this blanket be covered with a seal layer. The intent of the drainage blanket was to limit solute migration by capillary action. Research showed, however, that the drainage blanket would not be an effective means of controlling this mechanism of solute migration. Therefore, it was decided that the underdrainage system would be a better means of controlling solute migration and that the drainage blanket below the seal layer would be unnecessary. The revised cover system proposed by Morrison Beatty Limited, and supported by Ontario Hydro, involved a 3 component or 3 stage construction process. Figure 22 /16/ shows a schematic of this cover system.

A protective layer at least 1 m thick had to be placed over the seal layer to protect it from drying which could cause desiccation cracking and frost heave which could also cause cracking. A third layer of vegetated and contoured fill was designed to promote runoff and evapotranspiration of rainwater to limit infiltration into the cover.

Figure 23/16/ and Figure 24 show a contour map and cross section, respectively, of this cover.

5.2 Cover Construction

The first stage in the process was the construction of a seal layer, compacted to structural fill standards, with a minimum thickness of 1 m on top of the compacted fly ash. The seal layer was to be composed of compacted glacial till or another clay material that could meet the 10^{-7} cm/s hydraulic conductivity requirement and limit infiltration into the ash to about 0.4 L/s/ha. The construction of this layer required strict quality control. There were to be no lenses or pockets of granular material or organics that could allow increased infiltration. It was also suggested that special measures be taken to ensure that future construction does not breach this seal layer.

Till obtained from nearby construction excavations was examined for suitability as a material for use in the hydraulic seal layer. Some difficulty was encountered in locating suitable materials. At one point, the use of a soil with approximately 4% organics was proposed, however, this material was rejected because of the potential leakage that could occur through the organics or any voids they might cause upon degradation. Eventually, other sources of material suitable for the seal layer were located. Following laboratory testing and approval of the material by Ontario Hydro, construction of the seal layer began in June, 1987.

The seal layer was constructed using conventional construction equipment, including sheepsfoot rollers and vibratory smooth drum compactors. Construction was monitored by Golder Associates. They conducted grain size analyses and compaction testing of bulk samples, and permeability testing of tube samples taken from the compacted seal layer. Based upon the results of these tests, they found the material to be a suitable fill with a hydraulic conductivity ranging from 4.7×10^{-9} to 5.8×10^{-8} cm/s.

The second stage involved the placement of a protective layer at least 1 m thick on top of the seal layer. This was intended to protect the seal layer against desiccation cracking and ice-lensing due to frost penetration. Granular material, till, or broken rock were considered as viable materials for this layer as long as they were compacted to structural fill standards.

The third component of the cover will be an extension of the second. This erosion cover layer is to be sloped to the east with a minimum grade of 2% over the majority of its area. Near the corner, it was suggested to reduce this grade to 0.5% to lower the flow velocity and ensure acceptable levels of suspended materials before discharging into Mary Fix Creek. The thickness of this layer will be variable, but it could be constructed of the same materials as the stage 2 layer and compacted to structural fill standards as necessary. A topsoil cover and hydroseeding are recommended in order to limit erosion and cause evapotranspiration of any water that might enter this layer.

The hydraulic seal layer and the 1 m protective cover have been completed. Currently material is being stockpiled at the site for construction of the erosion cover that was shown in Figure 24. The completion date of this cover will be a function of the availability of suitable material.

5.3 Monitoring of Surface Water and Groundwater

Monitoring of surface water and groundwater is still ongoing and will continue for many years. Like conventional landfill sites, this one must also be monitored for the migration of leachate. Requests have been made to reduce sampling frequency and location to lower costs, however, the MOE must approve changes to the monitoring program. Monitoring of this site will likely continue for many years.

6.0 PROJECT OVERVIEW

This landfilling operation has again shown how coal ash may be used beneficially as a structural fill. Both Canada Brick and Ontario Hydro handled their responsibilities very well during the project, thereby making the project a success. Certain obstacles were encountered during the life of the project, but they were overcome. Like most other operations of this type, valuable information was gained while dealing with these challenges.

6.1 Obstacles Encountered

Some delays occurred during the approval process and EAB hearings which stressed the need for a thorough public relations program. EAB hearings were scheduled for December, 1980, and then were delayed until January, 1981, because a citizens' group felt they had not been given adequate time to prepare for the hearings.

Site investigations prior to seeking environmental approval were not sufficiently thorough. During the EAB hearings it was noted that data from hydrogeologic investigations was insufficient to fully describe the flow conditions and groundwater quality. The EAB hearings in January, 1981, had to be adjourned until April, 1981, so that additional hydrogeologic data could be gathered.

The approval process was lengthy. It took approximately a year and a half from application submission to approval and the commencement of landfilling. From project inception to approval took approximately 3 years.

During the landfilling operation, it was initially thought that the in situ ash densities were not adequate for the proposed land use. Measurements with a nuclear density gauge indicated that the density being achieved was less than the target density. However, plate load tests indicated that the ash should support the required foundation loadings. Canada Brick should be able to satisfy its obligation to provide land suitable for residential or light industrial development.

There were a few instances over the life of the project where dust fall exceeded MOE limits. However, these instances occurred during periods of high dust fall in other areas of the City. Therefore, the MOE was not greatly concerned with these isolated instances.

There have been minor changes in the water chemistry in Mary Fix Creek. Monitoring is still ongoing to determine the cause of these changes. Groundwater and surface water monitoring will have to continue until the MOE is satisfied that excessive volumes of leachate will not migrate from the site.

6.2 Conclusions

The disposal of ash below the groundwater table resulted in extra costs beyond those for above water table disposal. Extensive groundwater investigations and monitoring had to be implemented for this project. Monitoring must be continued indefinitely. A bond had to be posted prior to landfilling to cover for the cost of construction of a leachate treatment facility if necessary. The underdrainage system and access road were also costly to construct. The majority of operations problems occurred due to the influence of water in the quarry.

Due to the sensitive nature of projects of this type, preparation for environmental hearings requires a great deal of foresight. Approval for this project was delayed temporarily while additional hydrogeologic data could be gathered. Lack of important details may jeopardize approval or delay it significantly.

Operation of a quarry filling program is difficult in terms of water management particularly when there is no reliability in the supplies of incoming ash. As a result, it was necessary to operate small cells to keep ahead of natural rainfall, and have cells available for more ash than was forecast. By comparison, an above ground fill is much easier to control and manage, and is ultimately much less expensive. Above groundwater table filling sites would be preferred for future ash disposal.

To date there is no indication that any adverse effect on the groundwater quality due to placement of the fly ash has occurred/17/.

The testimony of the expert witnesses was vital to the approval of the project. These witnesses provided credibility and showed the MOE that Domtar and Ontario Hydro had investigated the possible impacts of this project and were interested in minimizing them.

Density testing and plate load testing showed that compacted fly ash is able to support the expected loads from residential or light industrial buildings with little settlement at densities as low as 85% of standard Proctor maximum dry density. A calibrated nuclear density gauge was an effective means of quickly and accurately measuring in situ ash density.

There are no reliable methods for predicting the ash content in a dust sample containing both shale and fly ash. Their similar elemental composition precludes chemical separation and their physical differences are not easily distinguishable.

This project indicates how a supportive organization (Domtar/Canada Brick) can help ash landfilling operations achieve approval and function efficiently.

The use of fly ash for a structural fill in a project of this magnitude was a "first" for Ontario Hydro. Valuable knowledge was obtained from the testing and monitoring conducted at this site. This indicates how important it is to monitor and document projects of this type so that the knowledge gained may be applied to future operations. There is still, however, a lack of comprehensive data pertaining to successful ash landfilling projects, however, this problem may be remedied by future research.

6.3 Recommendations

The search for future fly ash filling locations should focus on sites above the groundwater table. This will avoid the costs and problems associated with below water table disposal.

Ski slopes, toboggan hills or parks, where the public stands to gain further recreational land, should be the primary types of utilization projects for coal ash in the future. Public acceptance will be greater if the public knows they will see some benefit from the landfilling operation.

Ash filling operations should be done in areas where there is little residential development. People are becoming more environmentally conscious and opposition to a site near an existing residential area would be even greater nowadays. However, any landfill in rural areas would have to be carefully designed and monitored to ensure leachate does not contaminate local wells.

An in situ density target of 90% of standard Proctor maximum dry density should be sufficient for future filling operations of this type. This value was determined from plate load tests conducted on fly ash of different in situ densities.

Consultants should be hired to assist the proponent with projects of this type. They can be hired to assist directly with the project or as independent experts to review important aspects of the project, such as initial site investigations. Similarity between the findings of the proponent's investigations and those of a consultant help to illustrate the competence and integrity of the proponent.

Ash should be dampened prior to transport to avoid dusting and to accommodate easier compaction although a better method of ash dampening should be investigated.

Contractors who are unfamiliar with fly ash will require time to become accustomed to handling and placing ash. If possible, those contractors with previous ash handling experience would be preferred over those with no ash handling experience.

There is still a lack of valuable data from many of Ontario Hydro's past landfilling operations. Allowances should be made for extensive monitoring of future operations. This

monitoring may be costly in the short term, however, the data that is acquired will be valuable for supporting approval of additional fly ash utilization projects and will benefit ash management in the long term.

ACKNOWLEDGEMENTS

From the initial stages to the present time, this project has received invaluable input and support from many individuals and groups. It would be inconceivable to attempt to list the names of all of those involved. Nevertheless, there are certain individuals who do merit recognition.

Mr. J.H.P. Buckingham, of Ontario Hydro's Supply Division, negotiated the agreement with Domtar for the use of their quarry. Together with Mr. J. Nicks, he project managed the environmental approval phase of this project. In addition, he has coordinated Ontario Hydro's requirements and responsibilities involving the filling and close out operations with Domtar staff during the entire project. Mr. Buckingham's contributions were an essential part of this project.

The support of the project expressed by Mr. J. Nicks, Manager of Manufacturing for the Domtar Masonry Group, was vital during the quest for environmental approval. Mr. Nicks' endeavours are gratefully acknowledged.

Mr. L. Sylvester, Plant Manager for the Domtar Quarry, was responsible for the smooth operation of much of the filling project. The later stages of the filling operation were managed by Mr. J. Hewitt, who replaced Mr. Sylvester. The support of these two individuals helped to make this a successful filling operation. Their work is greatly appreciated.

The assistance with environmental monitoring provided by Mr. P. Griffiths of the City of Mississauga was important for ensuring this operation had minimum impact on the local environment. Mr. Griffiths' aid is thankfully acknowledged.

Mr. G. Nelson, an MOE representative, worked with Ontario Hydro and Domtar to ensure that they were operating within MOE guidelines. Mr. Nelson's guidance throughout the project is appreciated.

The hydrogeologic investigations and interpretations conducted by Mr. B. Beatty were essential for gaining environmental approval and successful operation of the project. Mr. Beatty's contributions are gratefully acknowledged.

During the EAB hearings Mr. A. Gardner was the legal representative for Domtar and Ontario Hydro. Mr. Gardner was very thorough and helpful during the hearings. Mr. Gardner's assistance is thankfully acknowledged.

Several employees of Ontario Hydro also supported this project. Dr. T.W. Klym provided valuable guidance regarding pit preparation and site operation. Mr. D. Dodd was responsible for directing the chemical analysis of groundwater, ash, and ash leachate. Mr. D.W. Abbott was in charge of community relations for this project. Mr. J. Kowalewski conducted investigations of noise due to the filling operation. Mr. C.B.H. Cragg assisted with pit preparation guidelines, underdrainage design, and other aspects of the project. The work done by these employees was essential in the quest for environmental approval and ensuring a successful landfilling operation. The input from each of these individuals is greatly appreciated.

Approved by:

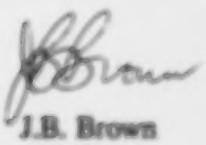

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TABLE I /1/

CHEMICAL COMPOSITIONS OF ONTARIO HYDRO FLY ASH LEACHATES

Constituent	Lambton G.S. (1)	Lakeview G.S. (2)	Nanticoke G.S. (3)	OCDWQ (4)
pH	9.6	9.4	11.0	6.5–8.5
Conductivity	134	355	183	
COD	7		2	
TOC	2.6			
Fluoride, F^-	0.9			
Alkalinity, OH^-	4.4	27	124	
CO_3^{2-}	50.3	57	32	
HCO^-	2.0	15	0	
Sulphate, SO_4^{2-}	1230.0	1980	480	500
Chloride, $Cl-$	3.4	84	28	250
Nitrate, NO_3^-	0.6			10
Lithium, Li	76.4			
Calcium, Ca	485	540	360	
Potassium, K	24	150	14	
Magnesium, Mg	0.9	7.8	0.7	150
Sodium, Na	56	370	41	
Barium, Ba	0.09	<5	3	1.0
Strontium, Sr	5.7		<4	
Silica, Si	1.8	0.6	0.8	
Aluminum, Al	2.2		<0.1	
Zirconium, Zr	0.009			
Beryllium, Be	<0.00005			
Iron, Fe	<0.001	<0.2		0.3
Titanium, Ti	0.005	0.5	<2	
Manganese, Mn	<0.001		<0.005	0.05
Vanadium, V	0.18		0.008	
Chromium, Cr	0.17	<0.23		0.05
Tungsten, W	<0.1			
Copper, Cu	0.0022	<0.0002		1.0
Molybdenum, Mo	0.620			
Silver, Ag	0.01			0.05
Cobalt, Co	0.002			
Nickel, Ni	0.002			
Phosphorus, P	0.075			
Zinc, Zn	0.085	0.02	<0.02	5.0
Boron, B	5.4	20	6.6	5.0
Bismuth, Bi	0.07			
Arsenic, As	0.024	<1	1	0.05
Tin, Sn	<0.001		<2	
Lead, Pb	0.001			0.05
Selenium, Se	0.018			0.01
Cadmium, Cd	0.0001	0.0002		0.005
Mercury, Hg	<0.0001			0.001

Notes: (1) 24-hour shake test (Ontario Hydro Research Report C79-142-K, 1979); (2) in ash concentration (Ontario Hydro Research Report 82-360-K, 1982); (3) field data (Nanticoke ash lagoon, Ontario Hydro Chemical Research Department, personal communication, 1985); (4) "Guidelines for Canadian drinking water quality (Department of Health and Welfare, 1979). All values are in mg/L except pH and conductivity.

TABLE II /5/

SUMMARY OF WATER QUALITY AT DOMTAR QUARRY PRIOR TO LANDFILLING

	Domtar Quarry #3 well		Drinking Water Maximum Acceptable Level /5/
	Shallow	Deep	
	801216		
ph	7.5	7.4	6.5 - 8.5
Conductivity mS/m	2400	5800	
Alkalinity (as $CaCO_3$) OH			30 - 500
Alkalinity (as $CaCO_3$) CO_3			30 - 500
Alkalinity (as $CaCO_3$) HCO_3	62	110	30 - 500
Sulphate	930	730	500
Chloride	8400	24000	250
Calcium	1410	4560	200
Magnesium	282	774	150
Sodium	4220	9710	270
Potassium	122	187	
Aluminum	<5	<25	
Arsenic	0.002	0.002	0.05
Barium	0.15	0.62	1.0
Boron	2.6	1.6	5.0
Cadmium	<0.0002	<0.0002	0.005
Chromium	0.003	<0.002	0.05
Copper	<0.001	<0.001	1.0
Fluoride	<4	<4	1.5
Iron	0.05	0.05	0.3
Lead	<0.002	<0.002	0.05
Manganese	<5	<25	0.05
Mercury	<0.0004	<0.0004	0.001
Molybdenum			
Nickel	<0.003	<0.003	
Selenium	0.008	0.003	0.01
Silver	0.002	0.003	0.05
Strontium			
Titanium			
Uranium			0.02
Vanadium	<0.1	<0.5	
Zinc	<0.02	<0.02	5.0

All values in mg/L except pH and conductivity

TABLE III

CHEMICAL ANALYSIS OF FLY ASH VERSUS THE DUNDAS SHALE

	*Typical Analysis, %	
	Fly Ash	Dundas Shale
Silica	44	56
Alumina	20	15
Iron	17	7
Calcium	3	5
Potassium	2	4
Sodium	1	<1
Sulphur	1	<1
Magnesium	<1	3
Titanium	<1	<1
Loss on Ignition	8	8

* Fly Ash also contains barium, boron, chloride chromium, manganese, and zinc in the hundreds of ppm range. Elements in the low tens of ppm include: cadmium, mercury, molybdenum, selenium, arsenic, copper, nickel, and lead /4/.

TABLE IV

Domtar Quarry Reclamation Project - Schedule

Date	Event
1978	- Ontario Hydro approached Domtar with proposal to fill quarry with fly ash.
June, 1980	- "Blue Book" - Proposed Reclamation Project for the Domtar Quarry was completed.
June 25, 1980	- An application to reclaim a 10 hectare section of an operating shale quarry in Mississauga was submitted to the MOE by Domtar.
Sept. 5, 1980	- "Project Backgrounder" was mailed to local interest groups by Domtar.
Sept. 10, 1980	- Advertisements for public information meetings about the project were published in the Mississauga Times and Mississauga News.
Sept. 15, 1980	- Flyers indicating that the public information meetings would be held on Aug. 27-28, 1981 were wrongly distributed to local residents. - This error created much curiosity and Domtar received many phone calls.
Sept. 16, 1980	- Flyers stating correct dates, Sept. 17 and 19, 1980, for public information meetings were delivered to local residents.
Sept. 17, 1980	- Advertisements of public meetings were to be re-run in the newspapers, however, the papers neglected to re-run them. - Public information meeting was held by Domtar at the Huron Park Centre.
Sept. 19, 1980	- Second public information meeting was held.
Sept. 24, 1980	- City of Mississauga held a public information meeting at the City Hall. - Mayor Hazel McCallion chaired this meeting at which Domtar made a presentation and the public was then able to ask questions.
Oct. 1, 1980	- Ontario Hydro and Domtar signed a legal agreement outlining the responsibilities of each company, operating guidlines, and legal obligations.

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TABLE IV (CONTINUED)

Dec. 8, 1980	- EAB hearings began. - An arrangement for Domtar to pay for an independent assessment of the "blue book" for the ratepayers' benefit was arranged. - Dr. J. Cherry of University of Waterloo was retained for this purpose. - The hearing was adjourned so that Dr. Cherry's review could be done. - Hearings were set to resume Jan. 19, 1981.
Jan. 15, 1981	- EHPHA held a meeting and asked that a Domtar representative be supplied to answer questions. - Dr. I. Joyce of Domtar attended this meeting.
Jan. 19-22, 1981	- EAB hearings resumed, testimony was heard from many expert witnesses. - Dr. Cherry indicated he would like more hydrogeologic data on the area in order to be confident with the groundwater quality and flow conditions around the quarry. - It was agreed that the hearings would be adjourned for three months so that additional hydrogeological information could be gathered.
April 6, 1981	- EAB hearings resumed. - Dr. cherry stated that he was satisfied that the hydrogeologic environment was understood and that there were no foreseeable hydrogeologic problems with the project. - Dr. T.R. Hamilton stated that fly ash was not harmfull if inhaled or ingested, thereby off-setting any health concerns.
Aug. 18, 1981	- Approval granted to Domtar by the MOE to begin landfilling project if certain provisions met. - Provisional Certificate # A220113 stated the conditions of this approval.
Dec. 18, 1981	- Filling of the quarry with fly ash commenced.
Dec. 30, 1986	- Last load of fly ash was placed and compacted, bringing the final total to 683,927.4 tonnes or 553,130.1 cubic metres of ash placed at the site.
June, 1987	- Construction of a minimum 1 m thick seal layer with a hydraulic conductivity less than 10E-07 cm/sec began.

TABLE V /14/

RESULTS OF LONG TERM PLATE LOAD TEST

Date	*Average Settlement, mm	Remarks
Feb. 8, 1983	0	5 min. after loading
Feb. 8, 1983	2.7	1 hr. after loading
Feb.10, 1983	2.2	
Mar.11, 1983	4.7	
Apr. 19, 1983	4.7	
May 12, 1983	4.7	
July 28, 1983	4.7	
Oct.31, 1983	4.7	

*Plate loading was 240 kPa

TABLE VI /3/

RESULTS OF PLATE LOAD TESTS ON ASH OF DIFFERENT IN SITU DENSITIES

Test No.	Plate Diameter (mm)	Fly Ash Density (% Proctor)	Plate Loading+ Maximum Pressurre (kPa)	Plate Loading+ Maximum Settlement (mm)
1	600	93.4	157	4.1
2	600	93.4	192	6.9
3	600	98.2	225	3.2
4	300	98.2	370	1.0
5	600	85.2	278	4.0
6	300	86.0	1246	7.3
7	300	100.2	1246	4.0

+ No soil failure occurred at maximum loading

TABLE VII /15/

RESULTS OF MOISTURE CONTENT STUDY

Date	Silo Number	Number of Samples	Moisture Content (%) Average ($\bar{x}$)	Standard Deviation (σ)
82 02 16	L - 1	46	19.4	4.1
	L - 4	39	20.1	4.7
	Hearn	9	21.8	5.5
82 02 17	L - 2	33	18.6	4.0
	L - 3	36	14.8	3.2
	Hearn	12	22.6	3.9
82 02 18	L - 1	43	18.0	3.2
	L - 3	32	15.6	2.7
	Hearn	21	21.8	4.7

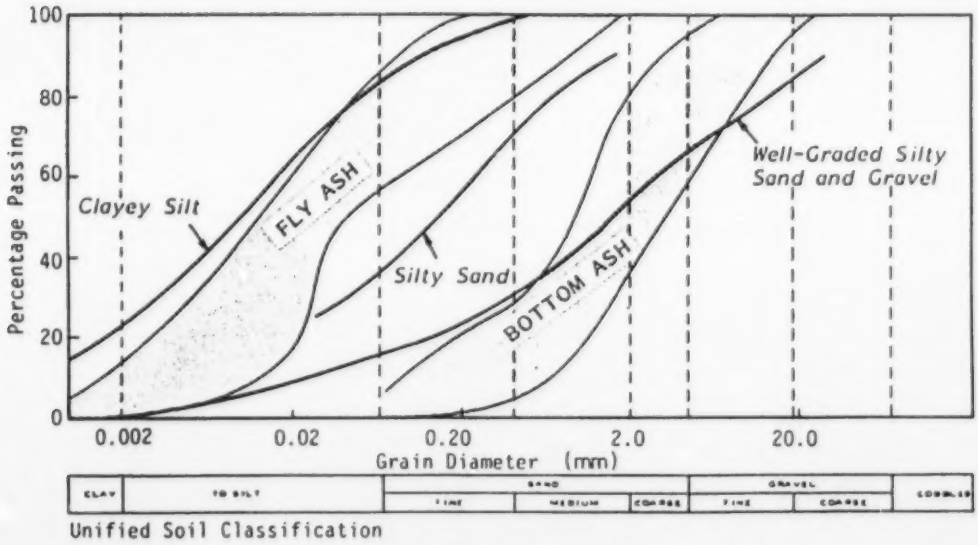

FIGURE 1 /1/

GRAIN SIZE DISTRIBUTION OF BOTTOM ASH AND FLY ASH

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FIGURE 2
MAP SHOWING LOCATIONS OF QUARRY AND GENERATING STATIONS
(BRAMPTON 30M/12E EDITION 4 ASE SERIES A751, 1964

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FIGURE 3 /7/

DOMTAR QUARRY CONTOUR PLAN

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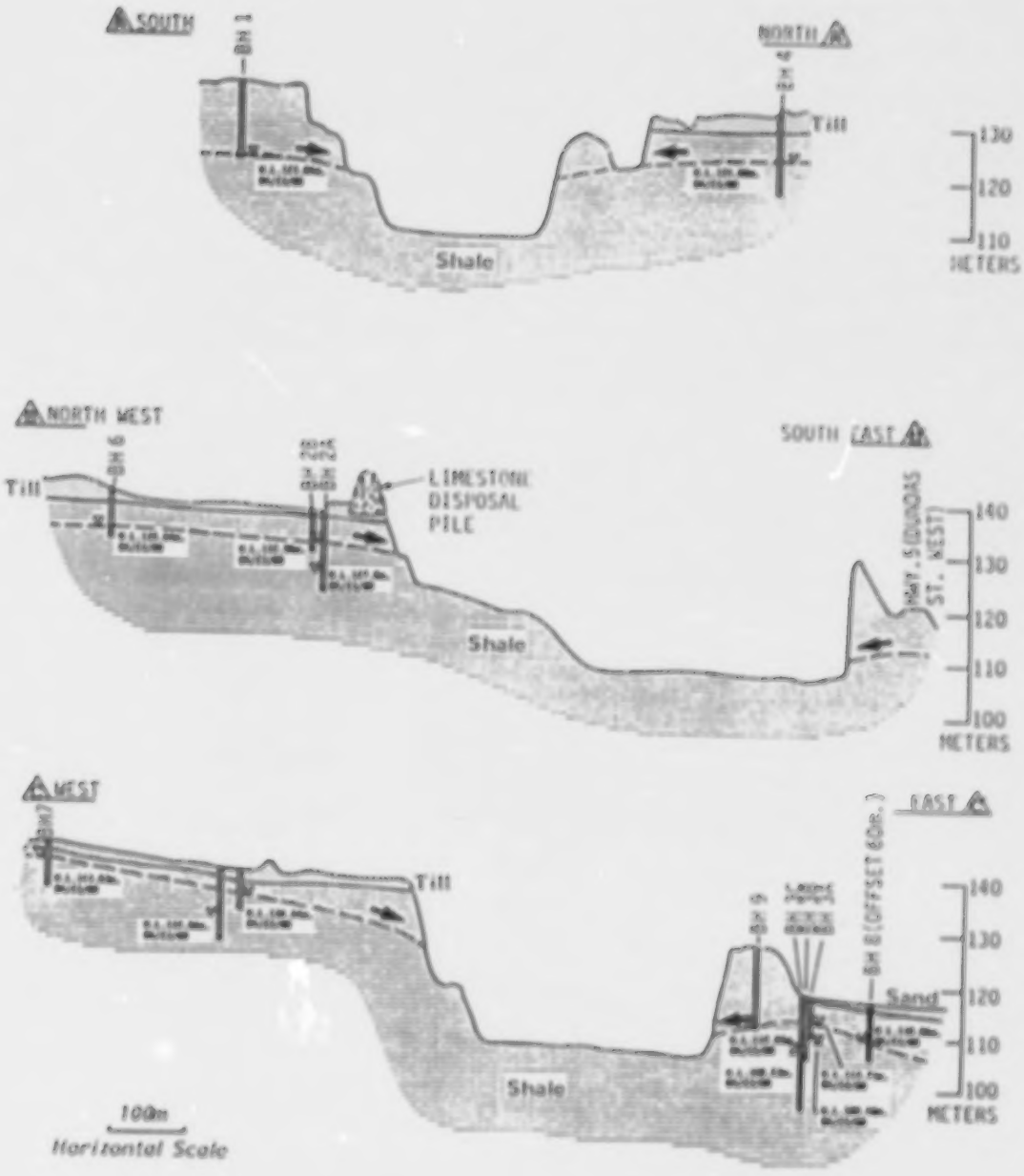

FIGURE 4

GEOLOGIC CROSS-SECTIONS OF THE DOMTAR QUARRY

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DOMTAR QUARRY

RECLAMATION PROJECT MISSISSAUGA

HYDROGEOLOGIC STUDY

LEGEND

BH-108 OBSERVATION WELL

DOMTAR PROPERTY BOUNDARY

HI-VOL SAMPLER

DUST JARS

SURFACE WATER SAMPLE STATION

FILLED AREA

BASE PLAN

1 acre

1 hectacre

FIGURE 5 /6/

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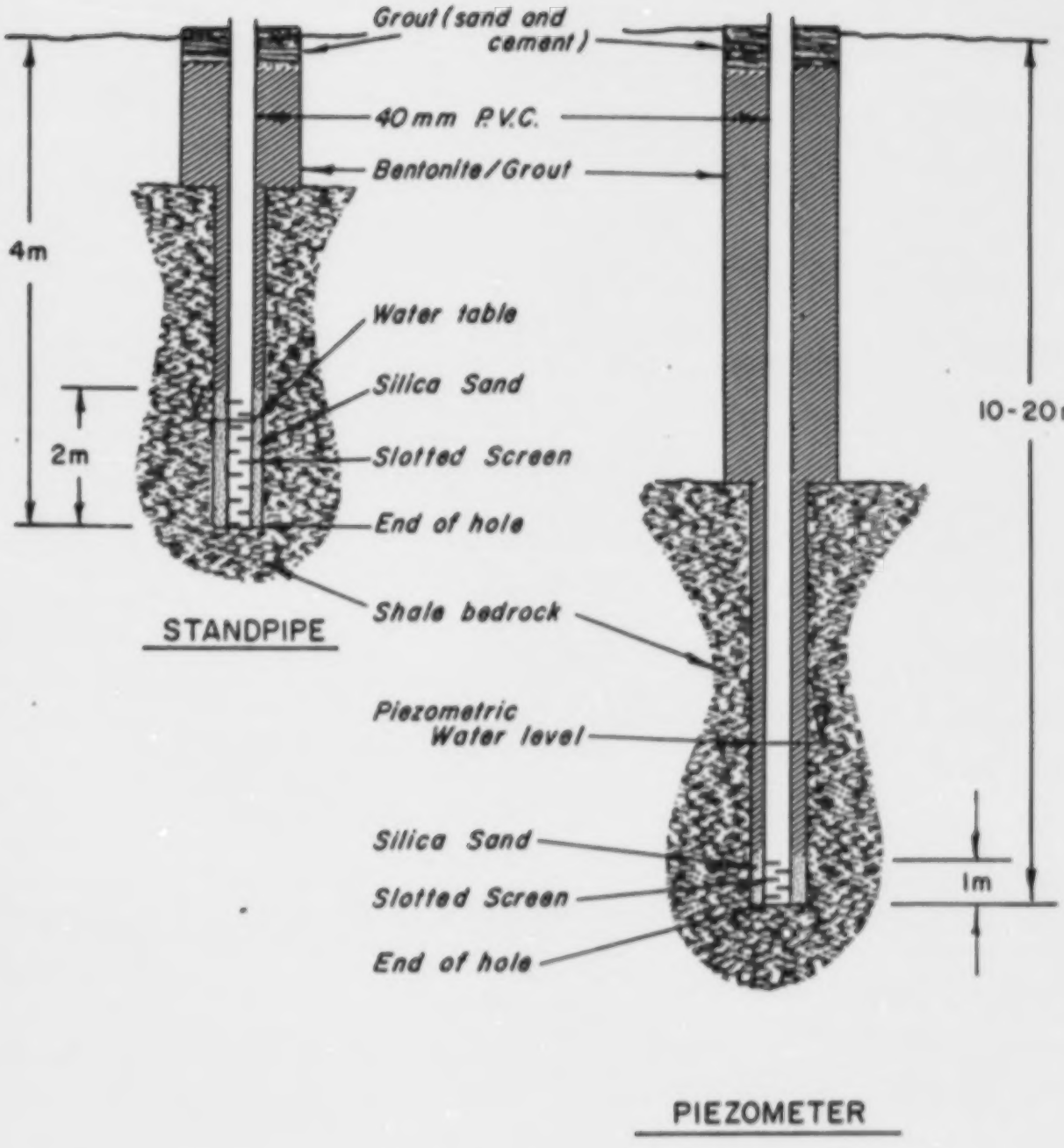

FIGURE 6 /5/

TYPICAL OBSERVATION WELL CONSTRUCTION

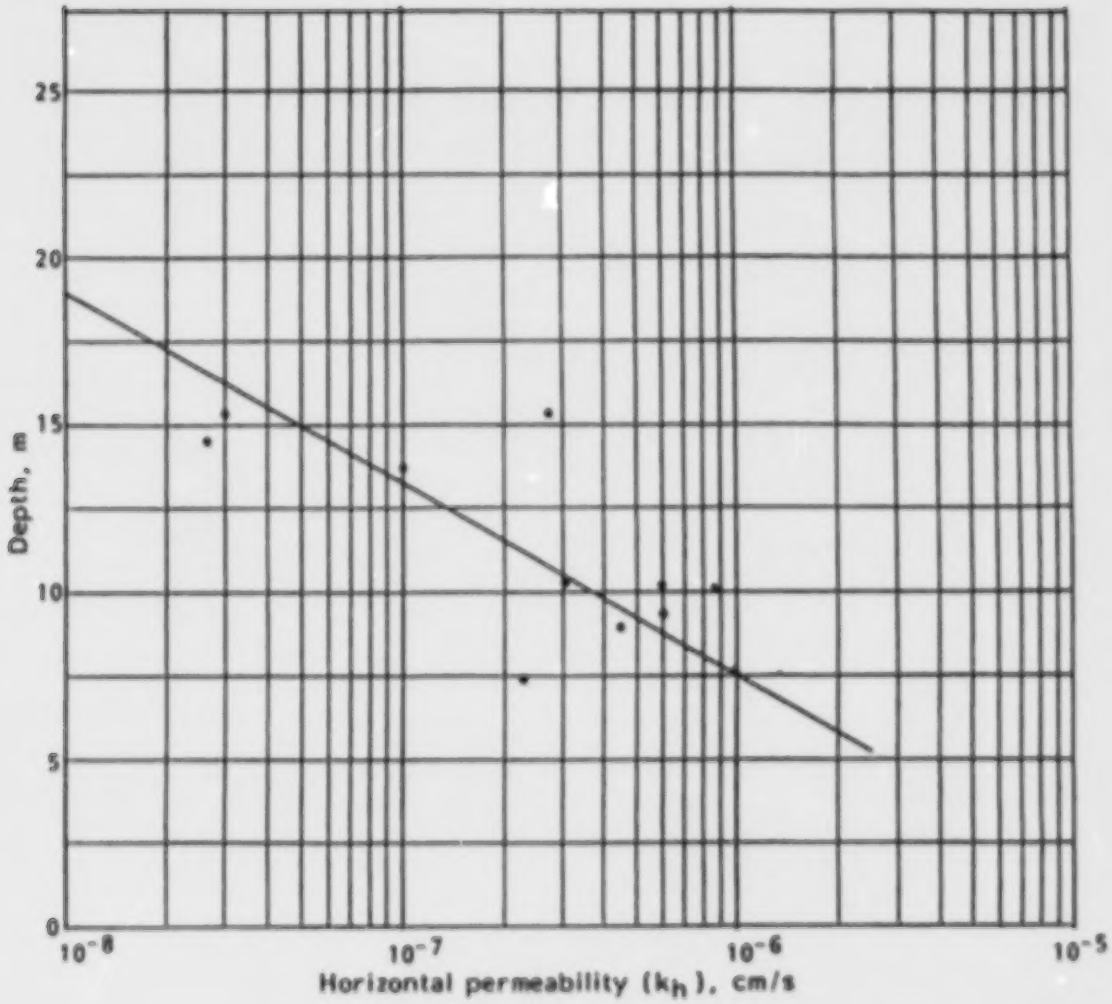

FIGURE 7.3

PERMEABILITY RESULTS

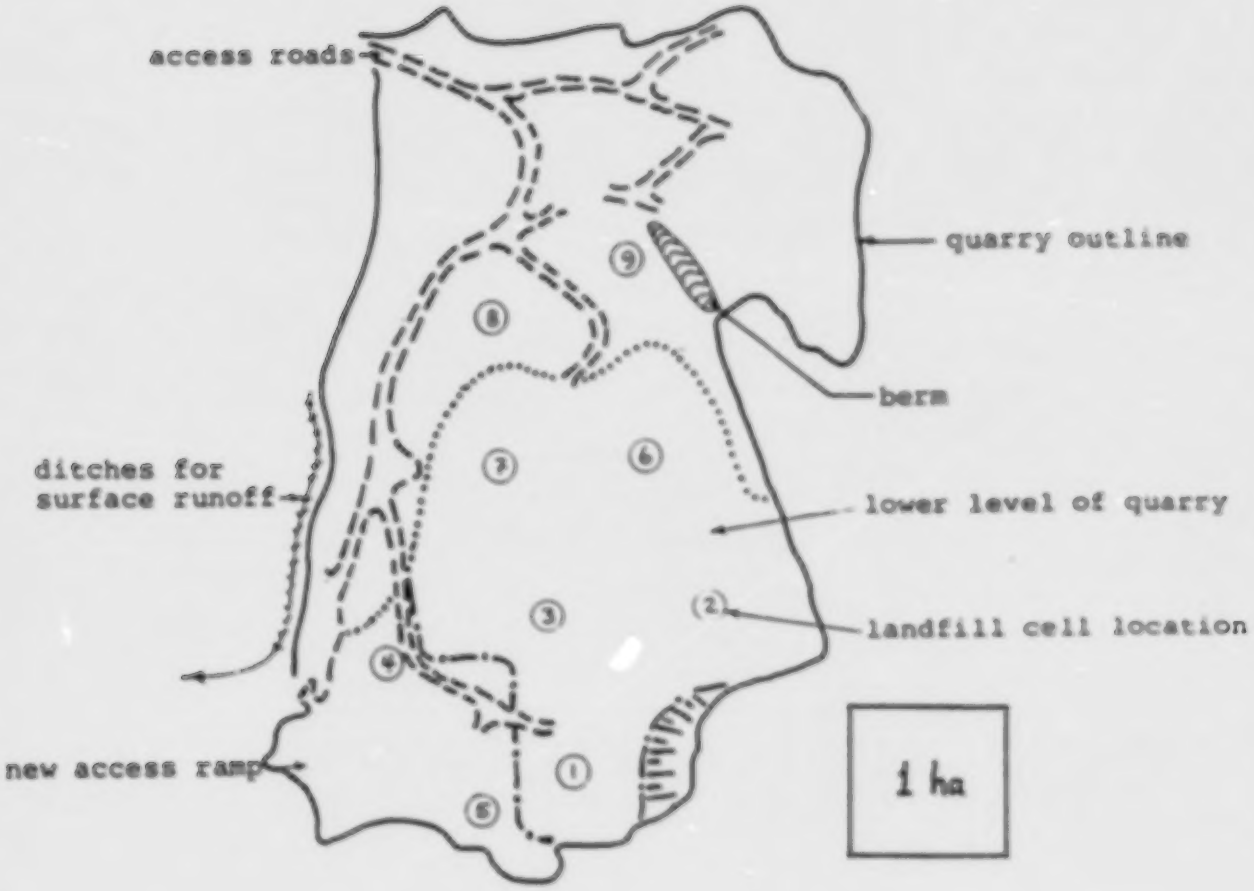

FIGURE 8 /8/

DOMTAR QUARRY PLAN SHOWING ACCESS ROADS

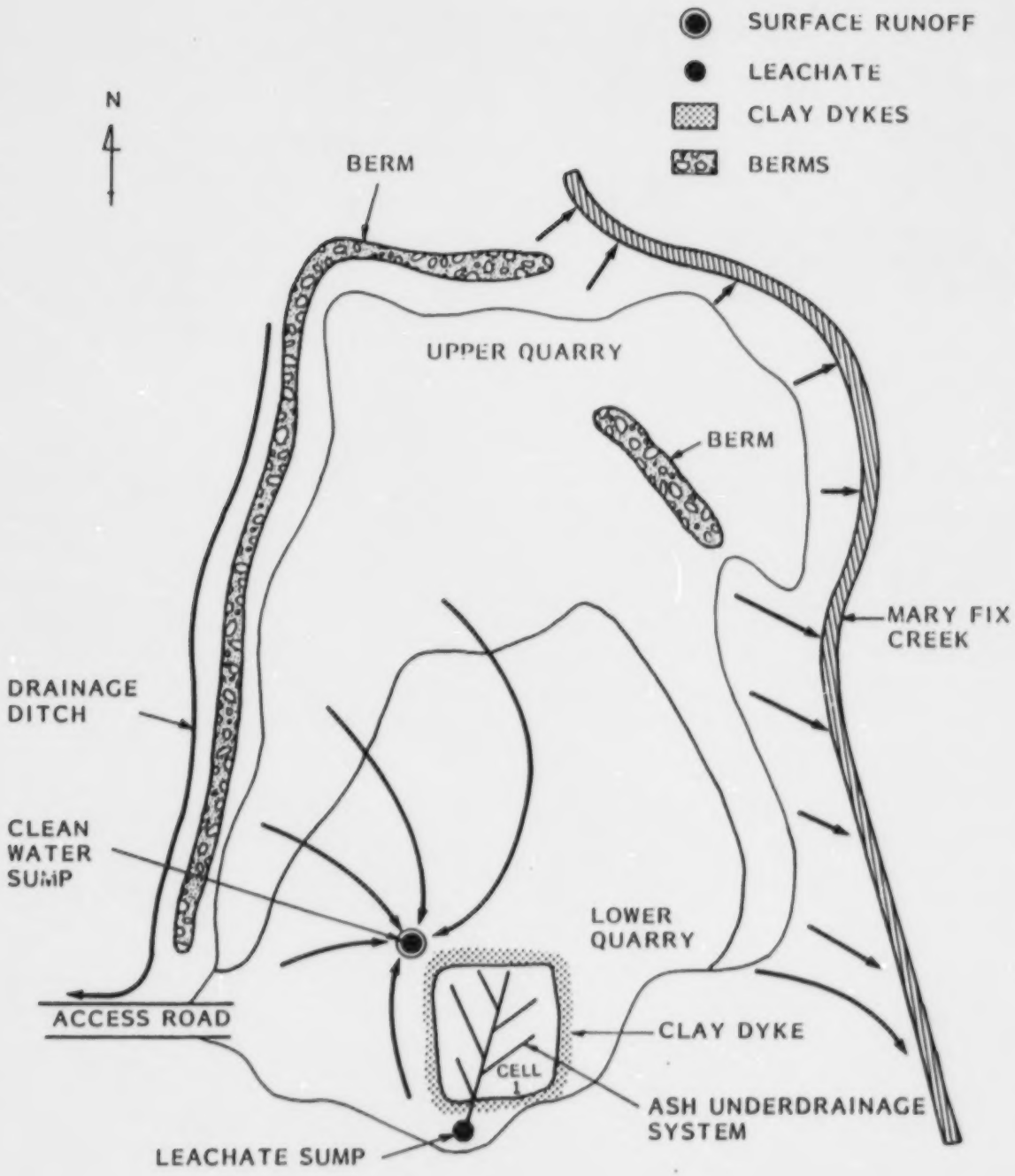

FIGURE 9 /3/

PIT DEVELOPMENT SCHEMATIC

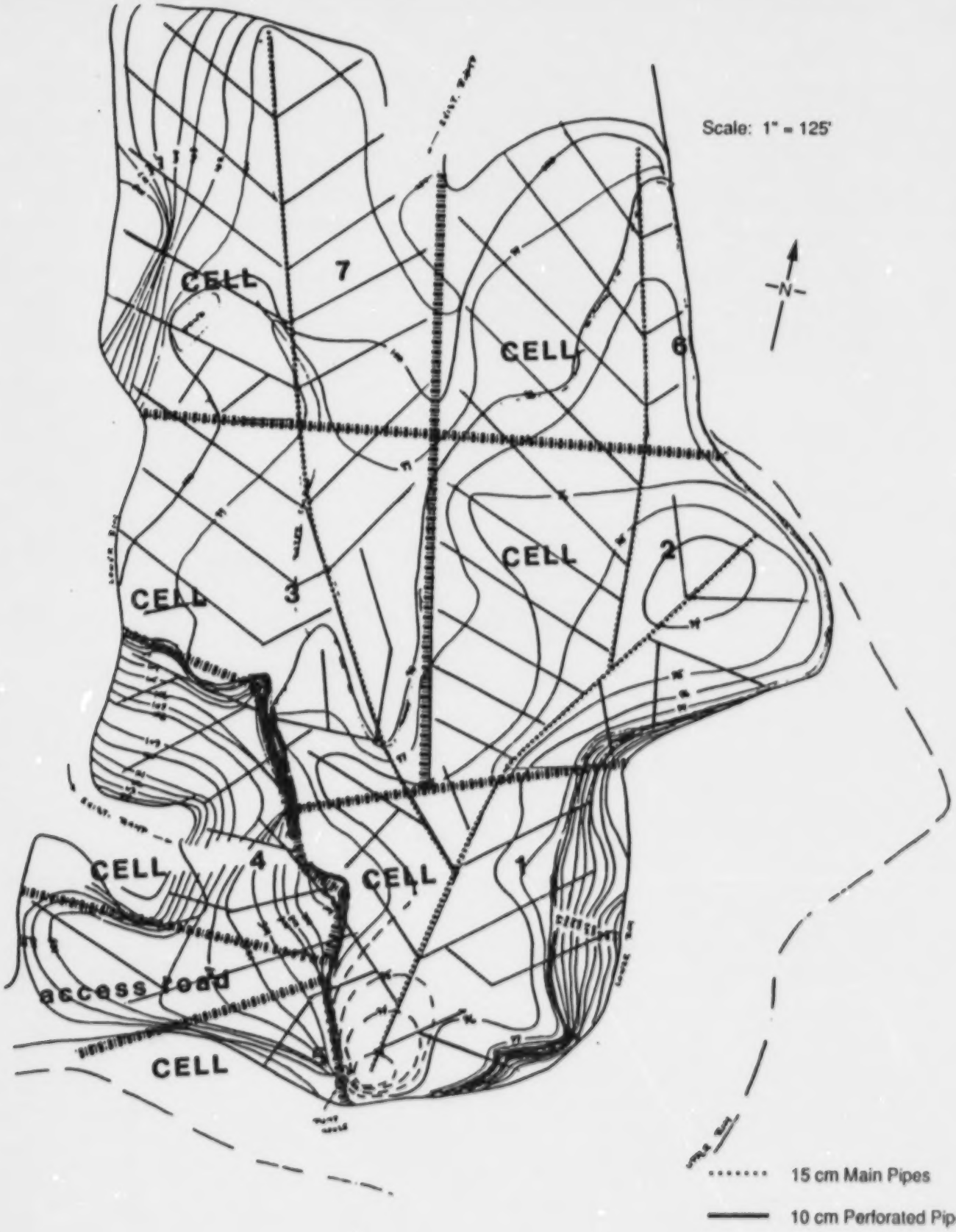

FIGURE 10 /8/

DOMTAR QUARRY UNDERDRAINAGE SYSTEM

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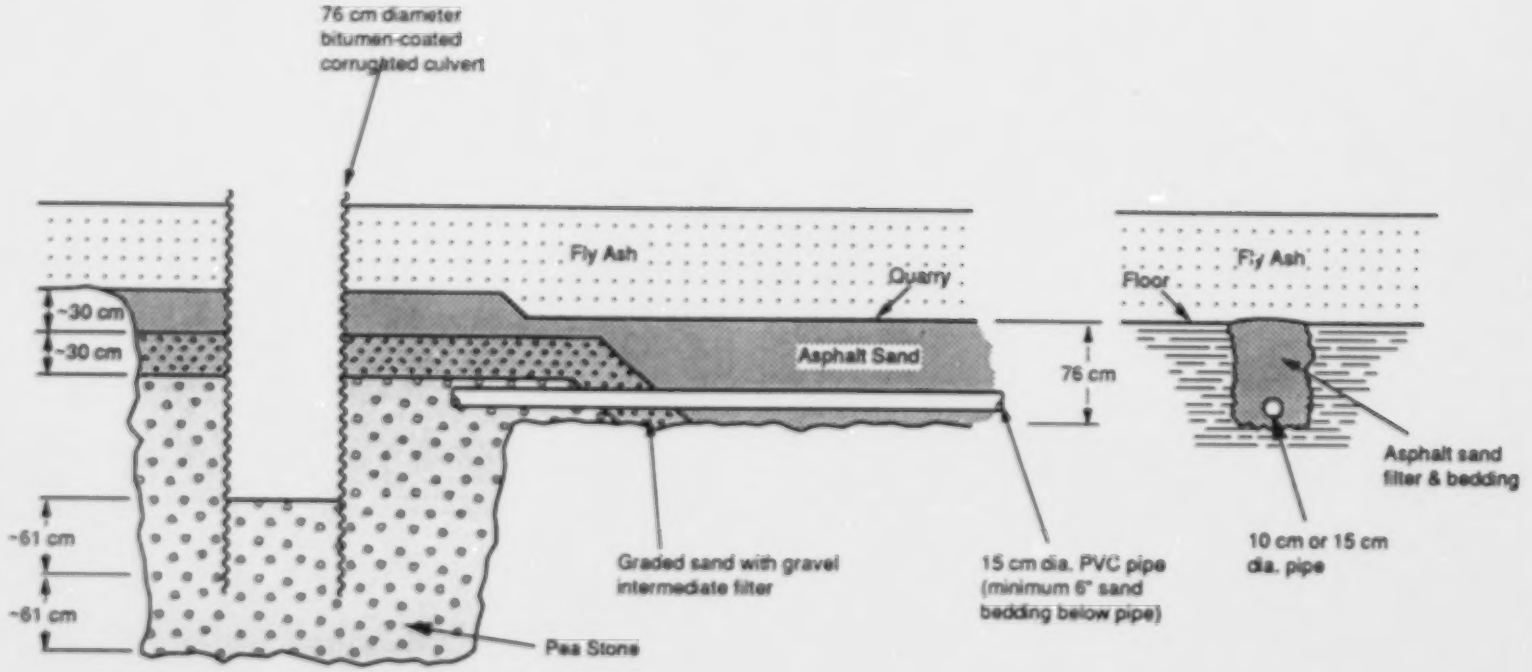

FIGURE 11 /9/

CROSS-SECTIONS OF LEACHATE SUMP AND UNDERDRAIN TRENCHES
FOR DOMTAR QUARRY LANDFILL

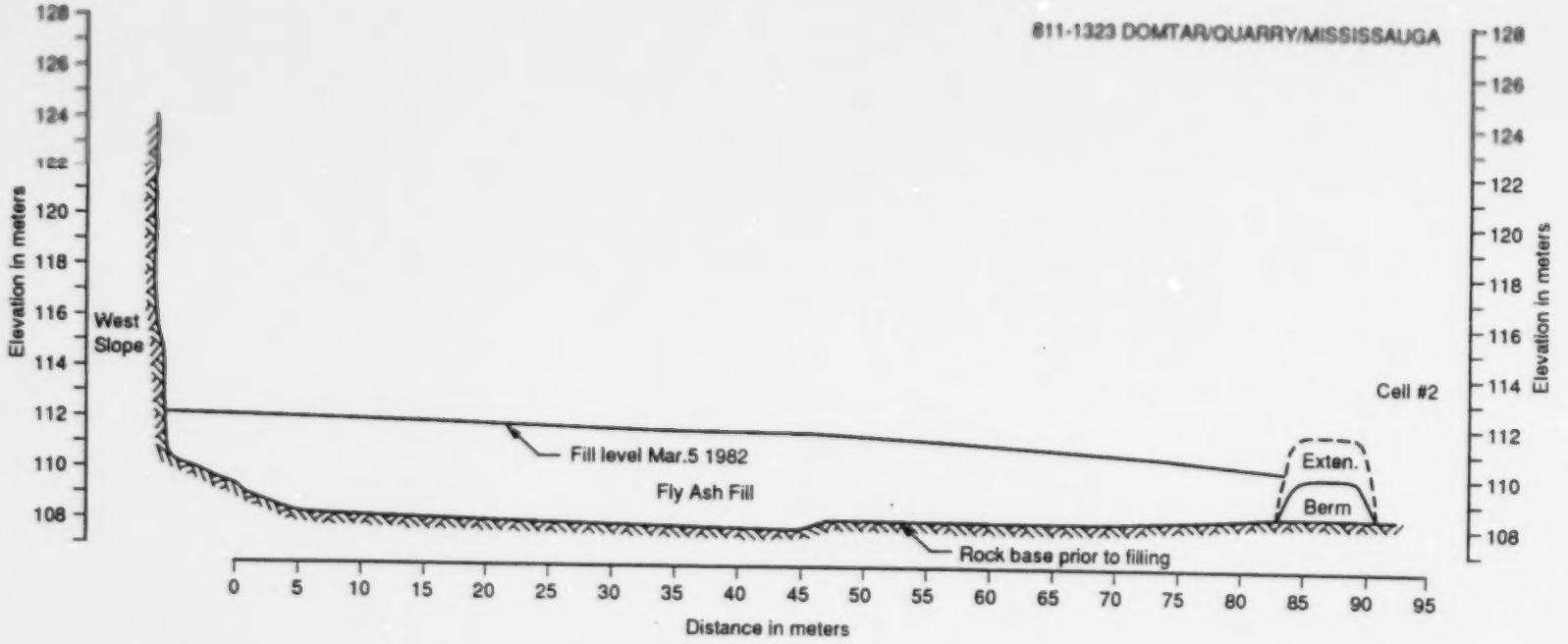

FIGURE 12 /10/

CROSS SECTION THROUGH CELL #3 SHOWING ASH FILLING AND CELL BERM CONSTRUCTION

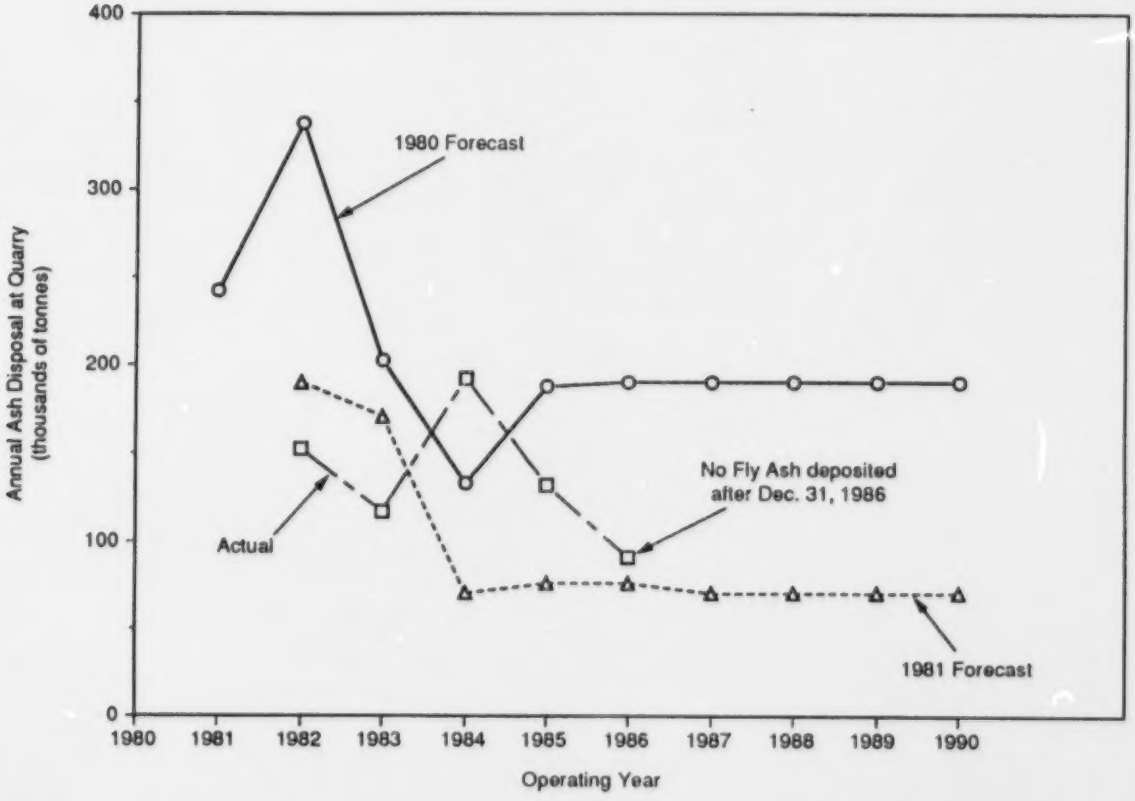

FIGURE 13 /3/

ASH PLACEMENT FORECASTS VERSUS ACTUAL PLACEMENT

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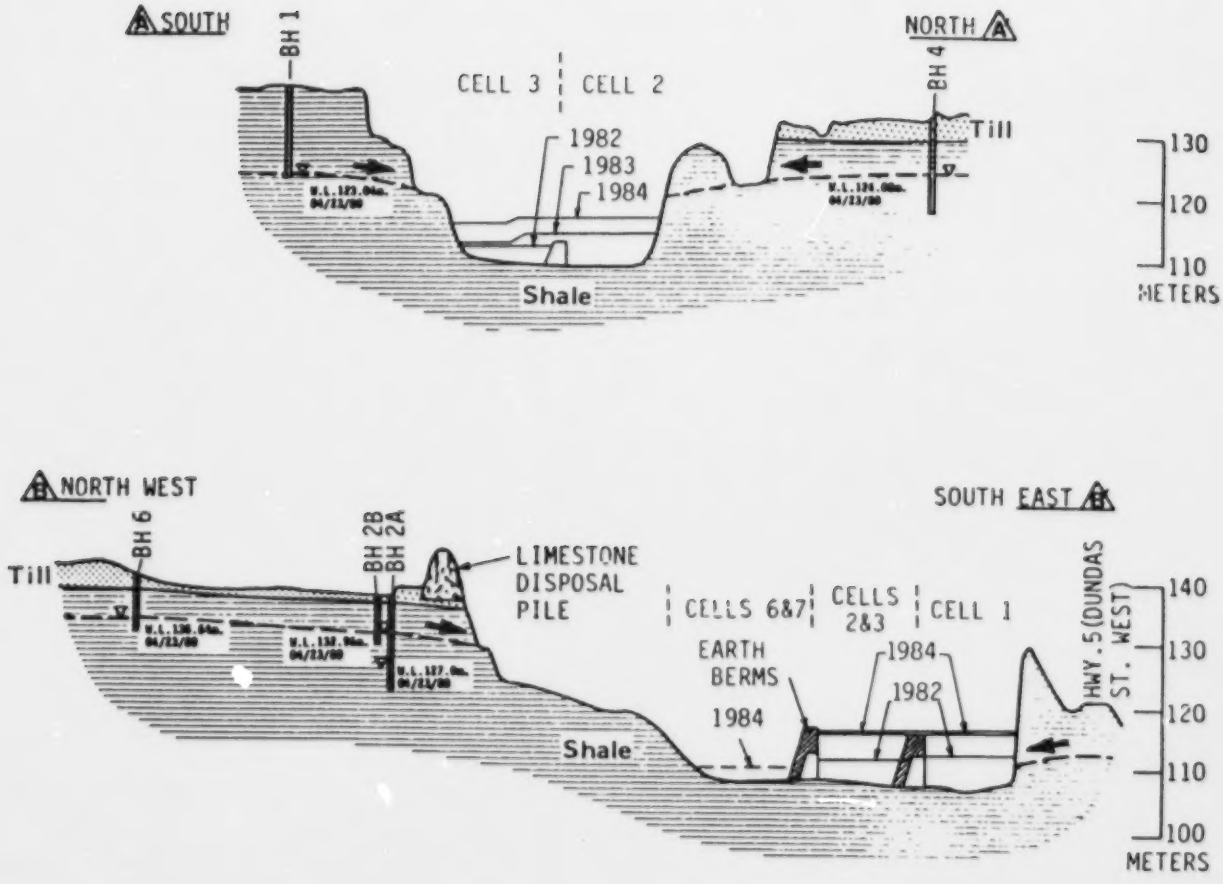
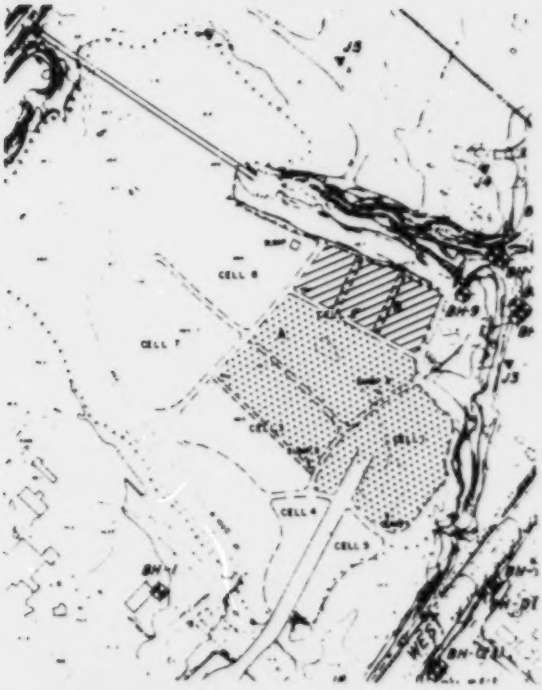


FIGURE 14 /3/

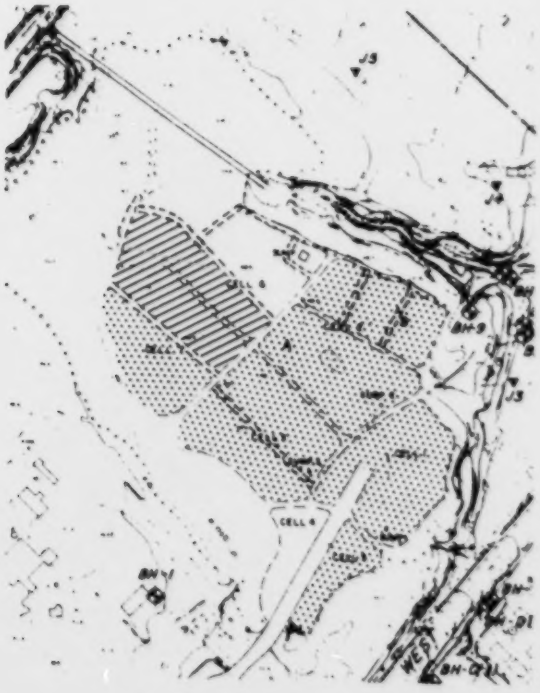
CROSS-SECTION SHOWING ASH FILL LEVELS

90-326
184994 RD



(a) OCTOBER 31, 1983

(b) OCTOBER 31, 1984



(c) OCTOBER 31, 1985

Area partially filled with fly ash

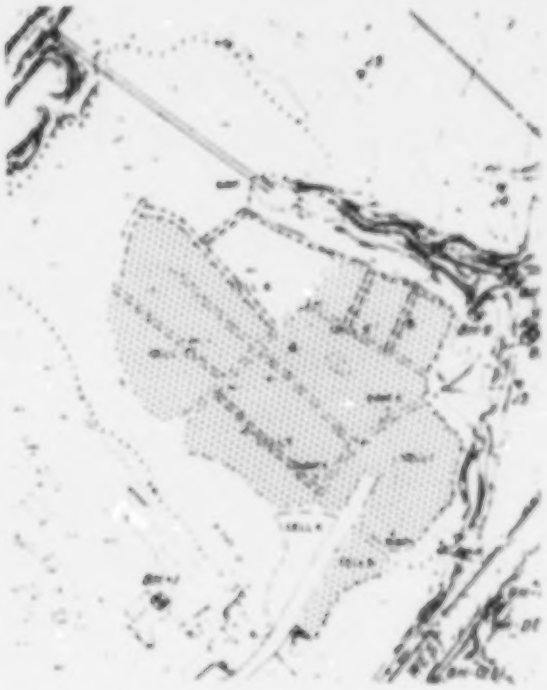
Area filled with fly ash and capped with clay

FIGURE 15 (a)

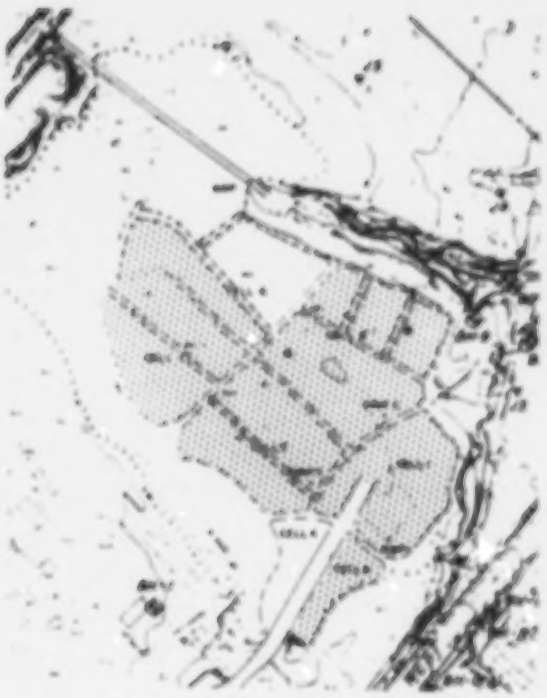
ASH FILLING SEQUENCE

90-326

184995 RD



(d) OCTOBER 31, 1986



(e) OCTOBER 31, 1987

(f) OCTOBER 31, 1988

Area partially filled with fly ash

Area filled with fly ash and capped with clay

FIGURE 15 (b)

ASH FILLING SEQUENCE

FIGURE 16

DOMTAR QUARRY
PRE-LANDFILLING

90-326
184907 RD

FIGURE 17

DOMTAR QUARRY
JULY, 1983

96-126
16/8/96 RD

FIGURE 18

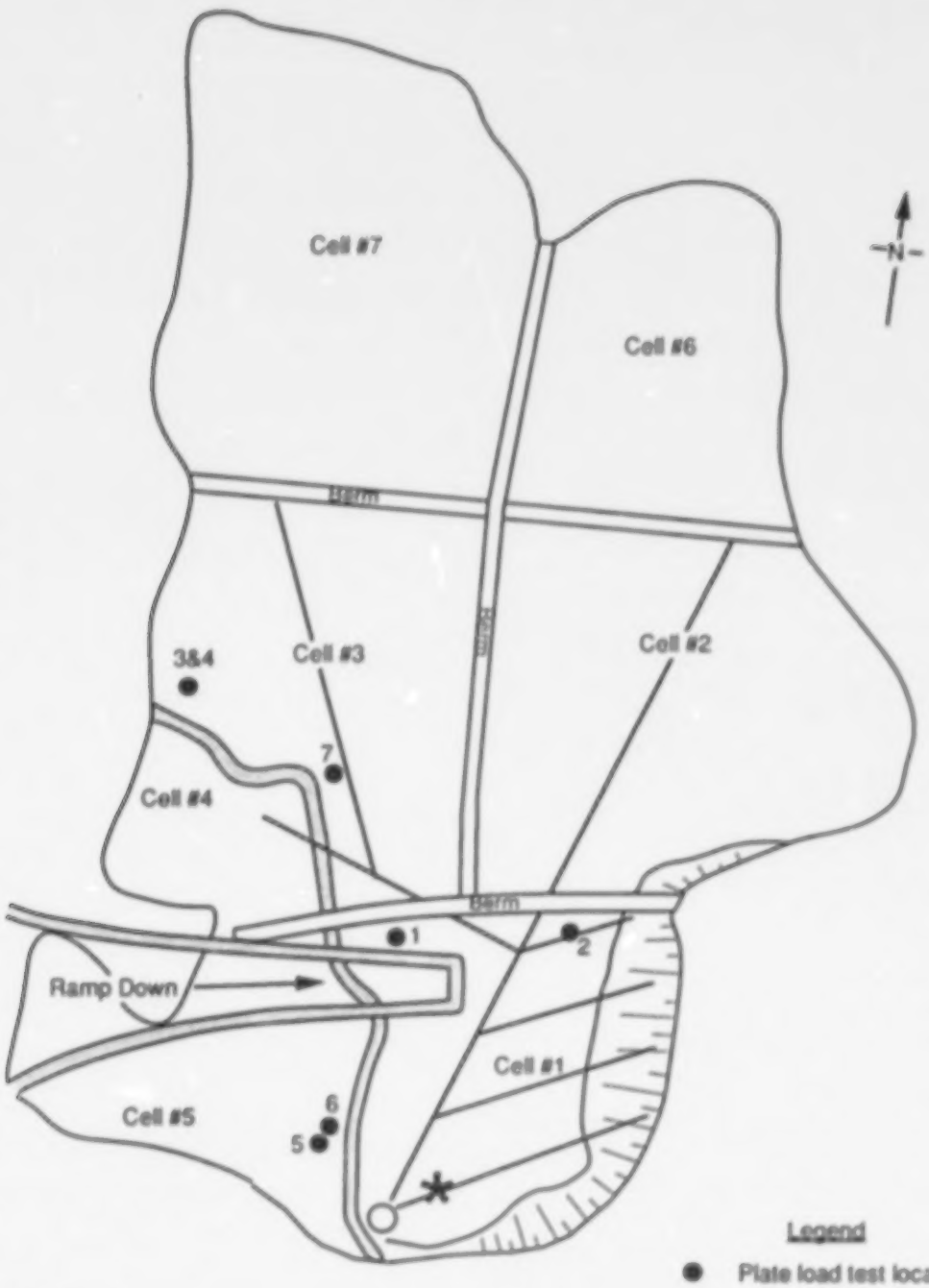
CANADA BRICK QUARRY
OCTOBER, 1985

90-326
185000 RD

FIGURE 19

CANADA BRICK QUARRY
SUMMER, 1987

90-326
184999 RD

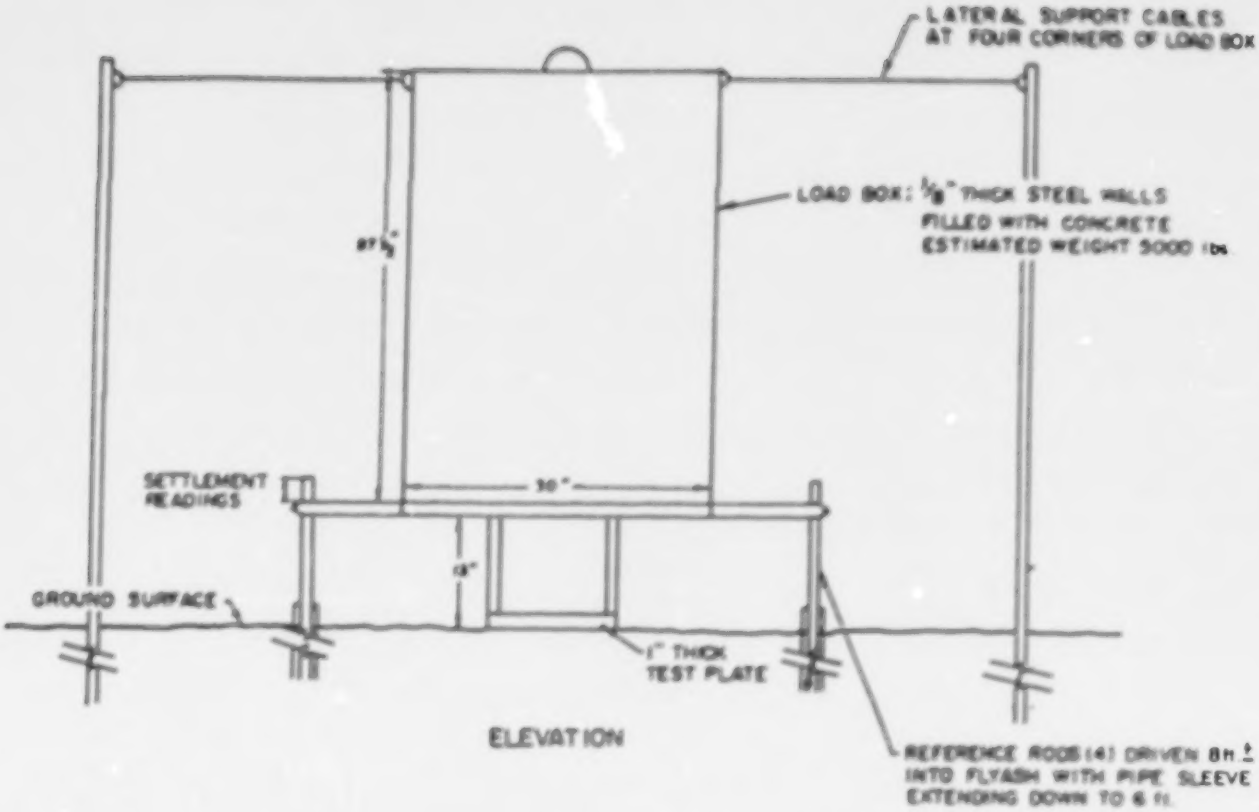


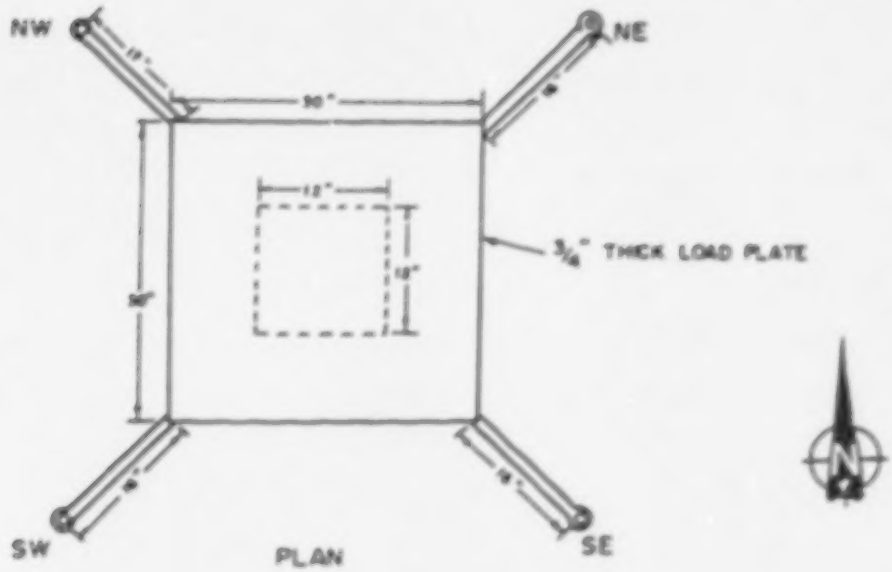
Not to scale
Traced from Domtar Figure 1
Dec.8, 1981

FIGURE 20 /12/

PLATE LOAD TEST LOCATIONS
DOMTAR QUARRY, MISSISSAUGA

90-326
185001 R0-AF40


LATERAL SUPPORT CABLES AT FOUR CORNERS OF LOAD BOX
LOAD BOX: 1/8" THICK STEEL WALLS FILLED WITH CONCRETE ESTIMATED WEIGHT 5000 lbs
87 1/2"
SETTLEMENT READINGS
30"
12"
GROUND SURFACE
1" THICK TEST PLATE
REFERENCE RODS (4) DRIVEN 8ft ± INTO FLYASH WITH PIPE SLEEVE EXTENDING DOWN TO 6 ft
ELEVATION

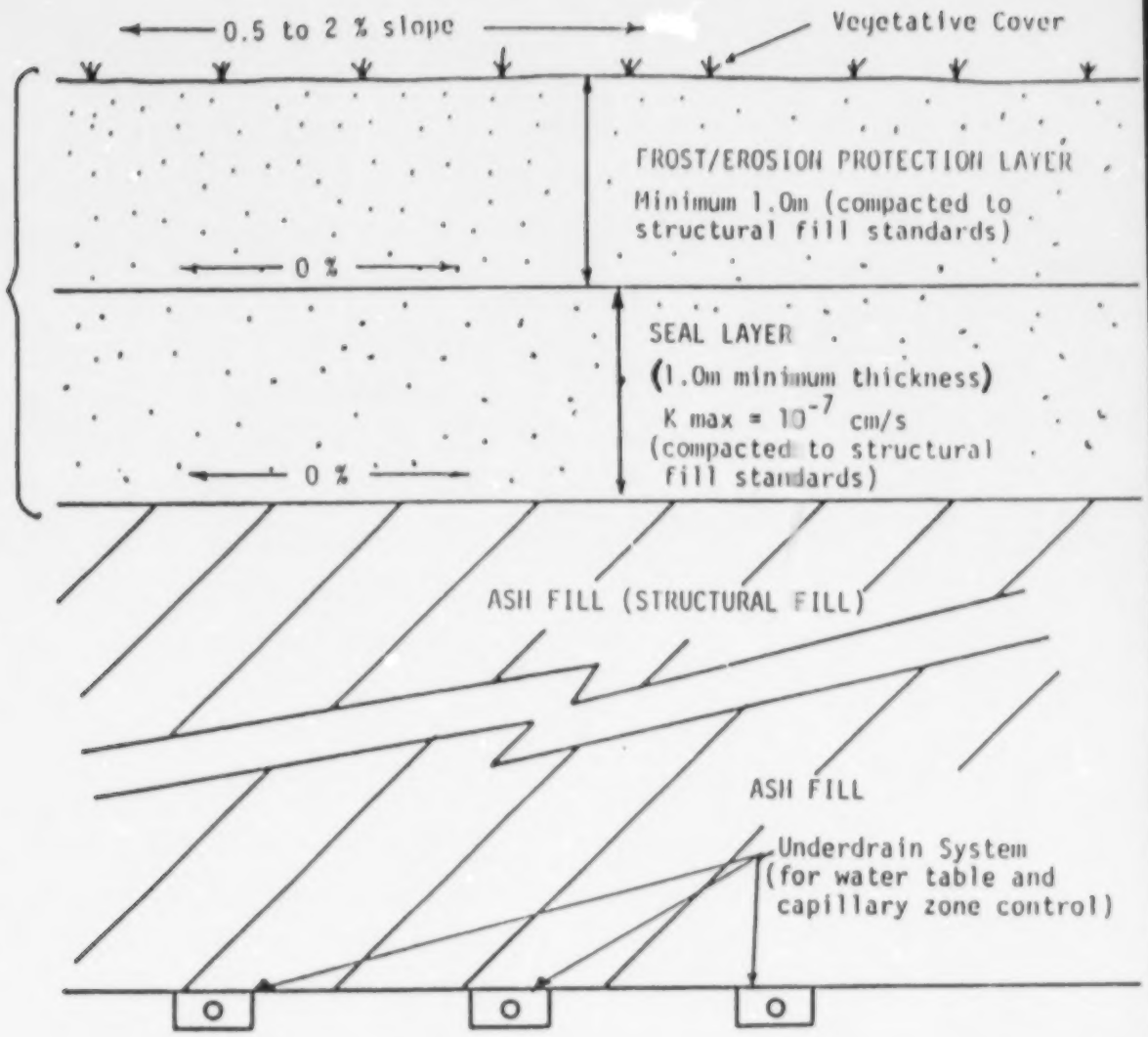


SCALE AS SHOWN

FIGURE 21 /13/

DOMTAR QUARRY TEST LOAD SET UP

90-326
185044 RD



NOT TO SCALE

NOTES:

1) All cover and seal material to be pre-qualified and inspected before placement.

2) All seal and interim cover soils compacted to specifications and insitu density certified by a qualified geotechnical engineer.

FIGURE 22 /16/

SCHEMATIC ASH-FILL COVER DESIGN CONCEPT
CANADA BRICK QUARRY
MISSISSAUGA. ONTARIO

90-326
185045 RD

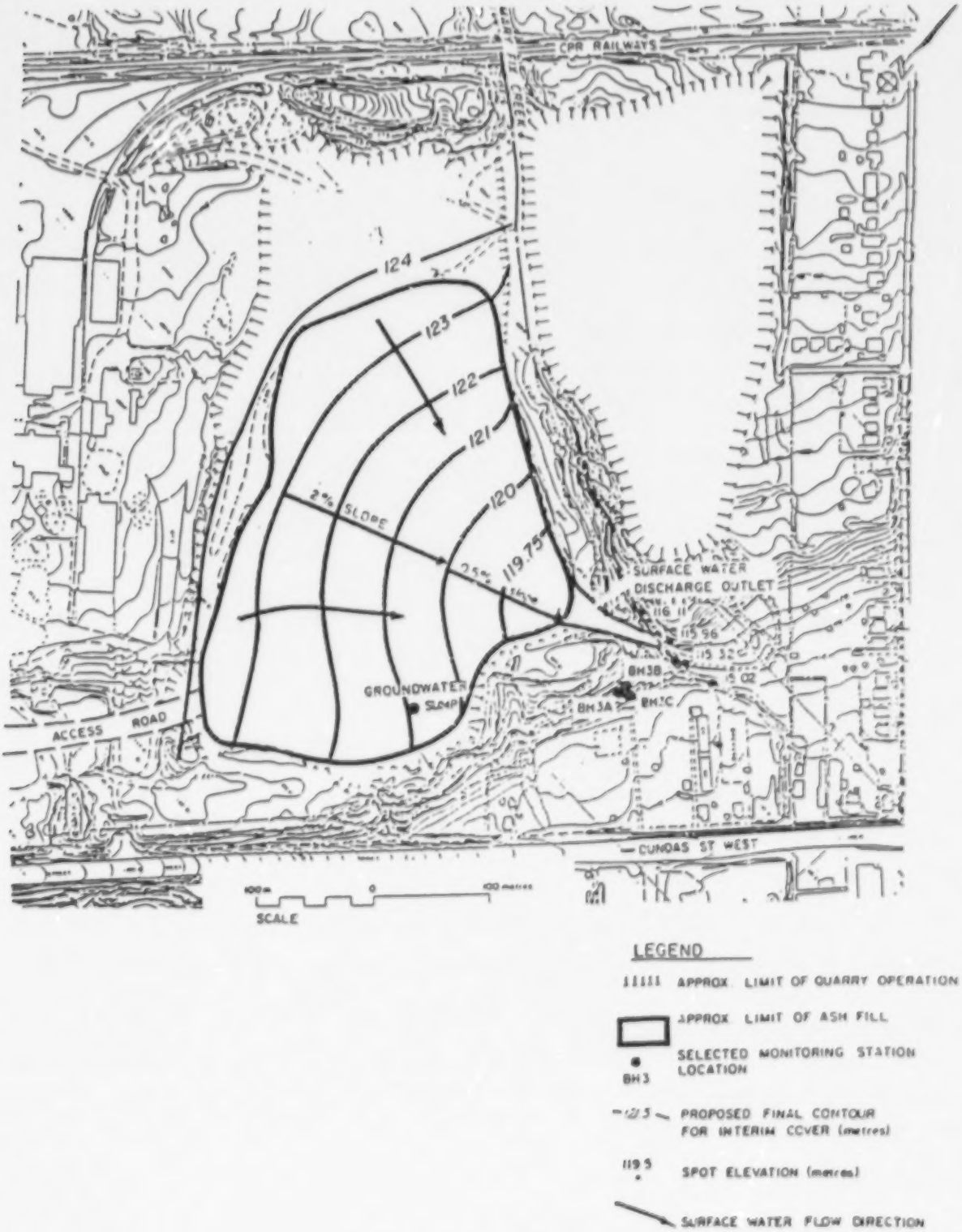


FIGURE 23 /16/

PROPOSED SURFACE CONTOURING FOR CANADA BRICK QUARRY RECLAMATION PROJECT MISSISSAUGA, ONTARIO

90-326
185046 RD

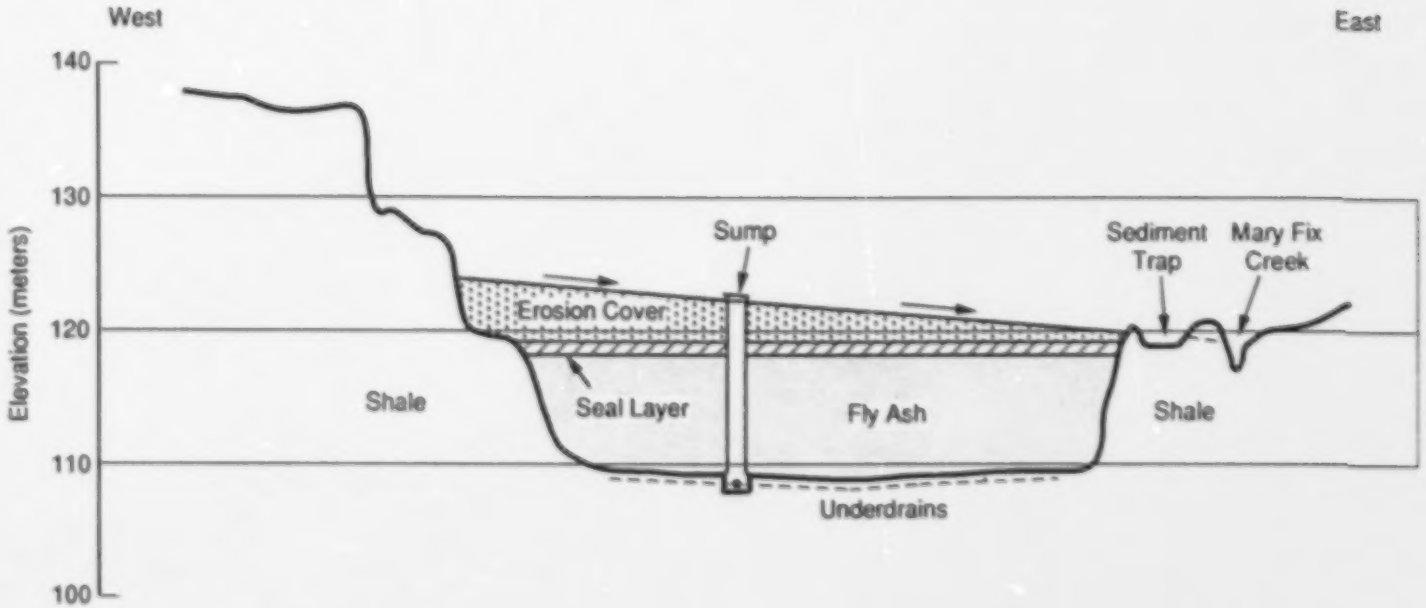


FIGURE 24

PROPOSED CLOSURE FEATURES FOR FLY ASH LANDFILL AT CANADA BRICK QUARRY

90-326
185048 RD AF40

Ministry of the Environment
Ontario

APPENDIX A

Provisional Certificate No.
A 220113

PROVISIONAL CERTIFICATE OF APPROVAL
WASTE DISPOSAL SITE

Under The Environmental Protection Act, 1971 and the regulations and subject to the limitations thereof, this Provisional Certificate of Approval is issued to:

Domtar Inc.,
3065 Mavis Road,
Mississauga, Ontario.
L5C 1T7

for the use and operation of a 10.1 hectare landfilling site within a total site area of 74.9 hectares.

all in accordance with the following plans and specifications: as listed in Schedule 'A'.

Located:
Part Lots 18, 19 and 20, First Conc. N. of Dundas Street
City of Mississauga,
Regional Municipality of Peel

which includes the use of the site only for the disposal of the following categories of waste (NOTE: Use of the site for additional categories of wastes requires a new application and amendments to the Provisional Certificate of Approval)
non-hazardous solid industrial waste limited to coal ash

and subject to the following conditions:

1. No coal ash is to be deposited at the site until a suitably designed program to monitor groundwater, surface water including Mary Fix Creek, leachate and dust is submitted to the Director of the Environmental Approvals Branch of the Ministry of the Environment for approval.

2. No coal ash is to be deposited at the site until the monitoring program referred to in condition 1 is approved by the Director.

3. A progress report on the landfilling operations including the following information:

   (a) the results, including an analysis of the results, of the monitoring program for groundwater, surface water including Mary Fix Creek, leachate and dust;

Dated this 18th day of August, 1981.

T. W. Crowe
Director, Section 39,
The Environmental Protection Act, 1971

90-32

Ministry of the Environment
Ontario

PROVISIONAL CERTIFICATE OF APPROVAL
WASTE DISPOSAL SITE

The following conditions are additional to the conditions shown on Provisional Certificate of Approval Number A 220113 dated August 18, 1981

(b) a site map of all newly and previously landfilled areas and any deviations from the operation and development plan;

(c) a summary of daily weights and volumes of coal ash deposited at the site;

(d) a soils report including the results of compaction tests on landfilled coal ash;

(e) environmental and operational problems encountered during the operation of the site and any remedial measures taken;

(f) a forecast of future coal ash weights and volumes and the anticipated remaining life of the site;

is to be submitted every twelve months to the Director and the Clerk of the City of Mississauga. The first report is to be submitted by December 31, 1981, with subsequent progress reports submitted annually thereafter.

4. An independent consultant, satisfactory to the Director, is to be engaged by the applicant to review the annual progress report referred to in condition 3 and submit written comments to the Director and the Clerk of the City of Mississauga. Written comments on the first report are to be submitted by December 31, 1981, with subsequent submissions to be made annually thereafter.

5. Within 2 months of the submission of the reports referred to in conditions 3 and 4, the applicant is to arrange a meeting with representatives of the Ministry of the Environment and officials of the City of Mississauga to review the reports.

6. No coal ash is to be deposited at the site until a report with respect to the funds necessary for the provision of and long term monitoring, maintenance and operation of suitable works for the treatment of leachate prior to discharge off-site is submitted to the Director.

7. No coal ash is to be deposited at the site until a commercial, irrevocable letter of credit issued by a Canadian chartered bank in the amount recommended in the report submitted pursuant to condition 6 and as approved by the Director and in the form satisfactory to the Director is submitted to the Director.

8. No coal ash is to be deposited at the site until suitable truck washing facilities have been provided at the site.

Ministry
of the
Environment
Ontario

PROVISIONAL CERTIFICATE OF APPROVAL
WASTE DISPOSAL SITE

The following conditions are additional to the conditions shown on Provisional Certificate of Approval Number A 220113 dated August 18, 1981

9. No coal ash is to be deposited at the site until this Certificate including the reasons for this condition has been registered by the applicant as an instrument in the appropriate Land Registry Office against title to the site and a duplicate registered copy thereof has been returned by the applicant to the Director.

10. This Provisional Certificate of Approval expires on December 31, 1983.